



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

B 458514

JUL 22 1912

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

RA

421

.M42

v. 8

CONTRIBUTIONS

FROM THE

SANITARY RESEARCH LABORATORY

AND

SEWAGE EXPERIMENT STATION

VOLUME VIII

REPRINTED PAPERS

PRICE \$1.00

BOSTON, MASSACHUSETTS

1912

From the Department of Biology and Public Health
Massachusetts Institute of Technology, Boston.

UNIVERSITY OF MICHIGAN
GENERAL LIBRARY



MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CONTRIBUTIONS

FROM THE

SANITARY RESEARCH LABORATORY

AND

SEWAGE EXPERIMENT STATION

VOLUME VIII

REPRINTED PAPERS

PRICE \$1.00

BOSTON, MASSACHUSETTS

1912

R.A.
421
.M42
v. 8

gift
 Dr. Frederick Herz
 9-14-57

TABLE OF CONTENTS

1. Introduction: WILLIAM T. SEDGWICK, Director
2. On the Relation of Illuminating Gas to Public Health. W. T. SEDGWICK and F. SCHNEIDER, Jr.. (*Jour. Inf. Dis.* 8, 1911, 380-408).
3. Investigation on the Purification of Boston Sewage. C.-E. A. WINSLOW and EARLE B. PHELPS. (*Jour. Inf. Dis.* 8, 1911, 259-288).
4. Sewage Purification; its Theory and Present Day Practice. EARLE B. PHELPS. (*Jour. Eng. Soc. of Penn.* 2, 1910, 447-479).
5. The Chemical Disinfection of Water and Sewage. EARLE B. PHELPS. (*Jour. Am. Pub. Health Ass'n.* 1, 1911, 618-622).
6. Has the Time Come for Double Municipal Water Supplies, one,—Naturally Pure—for Drinking and Cooking, the other—Denaturized or Sterilized for all Other Purposes. W. T. SEDGWICK AND L. P. LETTON. (*J. N. E. W. W. Ass'n* XXV, 1911, 440-453).
7. The Application of Certain Laws of Physical Chemistry in the Standardization of Disinfectants. EARLE B. PHELPS. (*Journ. Inf. Dis.* 8, 1911, 27-38).
8. The Milk Supply of Milwaukee and its Control by The Health Dept. SELSKAR M. GUNN. (*Bureau of Economy and Efficiency Bull.* No. 13).
9. Economy and Efficiency in Public Health Administration Work. SELSKAR M. GUNN. (*Nat. Mun. Rev.* I, 1912, 49-53).
10. Modern Board of Health Methods in Small Cities. SELSKAR M. GUNN. (*Journ. Am. Pub. Health Ass'n.* I, 1911, 373-380).
11. Modern Board of Health Methods in a Small Town. C. K. BLANCHARD. (*Journ. Am. Pub. Health Ass'n.* I, 1911, 369-372).
12. Natural Ice and the Public Health. W. T. SEDGWICK. (Address before Natural Ice Ass'n of America).
13. An Investigation into the Housing Conditions of Salem, Mass. S. M. GUNN and S. M. SCHMIDT.

INTRODUCTION

BY W. T. SEDGWICK, DIRECTOR

The present volume (the eighth in our series of reprinted papers) differs from those that have preceded it chiefly in the wider range of topics treated by the various authors. This broadening of the field is, however, merely a reflex of the general expansion now going on in all fields of Sanitary Science and Public Health.

If it is true, as the Director believes, that the last half of the nineteenth century was pre-eminently the Age of Darwin and Pasteur, it is natural that the first decade of the twentieth century should have witnessed a wonderful development of sanitary theory and practice, of the arts of sewage purification, disinfection, water supply, housing illumination, and especially of public health organization and administration. The table of contents of the present volume shows that many of these aspects of sanitary research and sewage experimentation are here touched upon, and reveals an energy, activity and enthusiasm on the part of some of the younger sanitarians of the day, characteristic of much of the work now going forward in our great modern Schools of Science and Technology.

Special attention is invited to the conclusions reached in the first paper which, if confirmed, ought to cause a general realization of the serious dangers to life and health brought about by the admission into our streets and our dwelling-houses of a poisonous and too often deadly form of illuminating gas. The papers next following, by Professors Winslow and Phelps, constitute important contributions to the theory and practice of sewage purification, as well as the chemical disinfection of water. The standardization of disinfectants is likewise a subject of great contemporary interest and importance. The papers by Professor Gunn, Mr. Blanchard and Mr. Schmidt, touch upon various administrative and scientific aspects of modern Board of Health organization and administration, and deserve special attention because of Professor Gunn's recent investigations in these directions for the Bureau of Economy and Efficiency of the City of Milwaukee.

Work of the kind here represented can, however, be organized, conducted and made available for public usefulness only by the expenditure of considerable sums of money, and we have again to express to the public-spirited and modest Donor, who has now for many years steadfastly but anonymously supported and stimulated this work, our sense of constant gratitude and obligation.

March, 1912.

ON THE RELATION OF ILLUMINATING GAS TO PUBLIC HEALTH.*

W. T. SEDGWICK AND F. SCHNEIDER, JR.

*(From the Sanitary Research Laboratories of the Department of Biology and Public Health, Massachusetts
Institute of Technology, Boston.)*

TABLE OF CONTENTS.

INTRODUCTORY.

MORTALITY FROM ILLUMINATING GAS POISONING IN MASSACHUSETTS: MORE THAN
1,200 DEATHS IN THE LAST 20 YEARS.

SOME DEATH RATES FROM SCARLET FEVER, FROM MEASLES, AND FROM ILLUMI-
NATING GAS IN MASSACHUSETTS AND IN RHODE ISLAND.

AMOUNTS AND KINDS OF ILLUMINATING GAS MANUFACTURED IN MASSACHUSETTS
(1886-1909).

A COMPARISON OF MORTALITY FROM ILLUMINATING GAS IN MASSACHUSETTS WITH
AMOUNTS AND KINDS OF GAS MANUFACTURED.

THE USE OF ILLUMINATING GAS IN MASSACHUSETTS FOR PURPOSES OF SUICIDE.

A STUDY OF THE SEASONAL DISTRIBUTION OF DEATHS FROM ILLUMINATING GAS
IN MASSACHUSETTS.

THE RELATION OF CERTAIN COMBUSTION PRODUCTS OF ILLUMINATING GAS TO
PUBLIC HEALTH.

THE PREVENTION OF POISONING BY ILLUMINATING GAS.

CONCLUSIONS.

APPENDIX.

A DIGEST OF LEGISLATION IN MASSACHUSETTS BEARING UPON THE RELATION
OF ILLUMINATING GAS TO PUBLIC HEALTH. (By Franz Schneider, Jr.)

INTRODUCTORY.

Sooner or later students of infectious diseases must give closer attention than they have yet found time to give to those environmental conditions which increase or diminish susceptibility to the various infections. When they do this, it will probably be found that obscure poisonings of various kinds play a large part in diminishing vital resistance and in increasing susceptibility. The facts presented in the present paper may be taken as a contribution to this end, for they show how in urban communities one of the commonest of public supplies—the ordinary gas supply—is today a constant menace to the public health, attended as it is not

* Received for publication July 28, 1911.

only by numerous fatalities but also by many non-fatal poisonings which signify widespread atmospheric impurity in urban dwellings.

The following discussion deals directly and for the most part statistically with *fatalities* from gas poisoning, but the reader must not for a moment suppose that these alone are of importance. Probably even more important are various obscure consequences of the leakage of illuminating gas in private dwellings, in public halls, and in public streets, which are as yet seldom thought of and even more seldom detected.

In 1885 an article bearing the same title as the present paper appeared in the *Annual Report of the State Board of Health, Lunacy, and Charity of Massachusetts*. It was carefully prepared by the able secretary of the Board, the late Dr. Samuel W. Abbott, and the reason for its appearance at that time was the recent perfection of a simple and convenient patented process for the manufacture of a new kind of illuminating gas, then and since known as "water-gas." This was placing upon the market an illuminating gas easier and often somewhat cheaper to make, and ranking higher in candle power, than the ordinary coal-gas derived by the distillation of bituminous coal, but a gas also much more heavily charged with the well-known poisonous substance, carbonic oxide (CO). Promoters of the new process naturally urged its adoption upon the old and established gas companies, which in some cases began to make use of it, especially for supplementary supplies, but in other cases, particularly if they were already prosperous, refused to have anything to do with it. Advantage was also taken of the water-gas process to form new and competing companies, charters being sought on the promise of lower prices and higher candle power for gas. Attempts were likewise made to buy out at low prices long-established and prosperous companies occupying inviting territory, by threats of invasion and competition through gas of lower price and higher candle power.

In Massachusetts, a comparatively thickly settled and therefore attractive territory for the manufacture and sale of gas, there were in the early 80's many and prosperous gas companies, and these for the most part, under the leadership of the largest—the Boston Gas Company—refused to adopt the new process or to be frightened

by threats of competition into selling out at low prices. Furthermore, when the water-gas interests undertook to obtain charters in Massachusetts for new and competing companies they encountered a formidable obstacle in a statute (enacted in 1880) forbidding the distribution and sale of illuminating gas containing 10 per cent or more of CO. This law it was therefore necessary to have annulled before the new process could be introduced into Massachusetts.

A battle royal for the repeal of the law now began between the older coal-gas companies on the one side, who did not care to pay for and use the new process, or did not desire to sell out to the new companies, or did not want competition, and those newer companies which for one reason or another wished to enter Massachusetts territory and sell and distribute water-gas containing more than 10 and often as much as 30 per cent of carbonic oxide. Popular attention was drawn by the old gas companies to the sanitary aspects of the question, and the battle before long raged fiercely around the question of the public health. Meantime the State Board of Health, Lunacy, and Charity referred the mooted question of the relative poisonous properties of the two gases, coal-gas and water-gas, for investigation to two professors of the Massachusetts Institute of Technology—one, the eminent sanitary chemist, the late William Ripley Nichols, and the other, a physiologist, one of the present authors (W. T. S.). These investigators soon after made a report, based upon extensive experiments upon animals, showing that, as might have been expected, much greater danger exists in water-gas than in the ordinary coal-gas (*Report of State Board of Health, Lunacy, and Charity for 1885*, p. 275). In the same report Dr. S. W. Abbott, then secretary of the Board and an excellent statistician, published the paper already referred to above in which he showed that for the preceding 20 years there had been but four deaths from gas poisoning in Massachusetts and predicted many more if the 10 per cent limit should be abandoned.

Victory in the legislature rested for a time with the older companies. But in 1888 the Gas Commissioners, who had been created in 1885, were empowered to license certain companies to make and sell water-gas for illuminating purposes, and in 1890 the 10 per cent statute was repealed, because meantime the opposition of the older

companies was for one reason or another relaxed, while the State Board of Health (as it was now and had since 1886 been called) made no effective objection. Commercial conditions had changed, and many of the coal-gas companies now wanted the privilege of making water-gas if it suited their convenience. Moreover, water-gas was being widely used in other states without public protest, and when the commissioners recommended the change it was speedily made by the legislature—with what obviously disastrous consequences to the public health we shall see in the present paper. Of the unobserved and perhaps imperceptible consequences such as diminution of vital resistance and increased susceptibility to disease, either constitutional or infectious, we have, and in the nature of the case can have, no exact knowledge. There is reason to believe, however, that here also the consequences, if less disastrous, have been no less real.

**MORTALITY FROM ILLUMINATING GAS POISONING IN MASSACHUSETTS:
MORE THAN 1,200 DEATHS IN THE LAST 20 YEARS.**

It was predicted by the investigators employed by the State Board in 1884 and reaffirmed by Dr. Abbott in 1885, that if water-gas should replace coal-gas in Massachusetts the consequences to the public health would probably be dangerous if not disastrous. Other experts of equal or greater eminence took precisely the opposite ground and even ridiculed the possibility of any such consequences. Among these were Professor C. F. Chandler, of Columbia University, and the distinguished English chemist, Dr. E. Frankland, who stated in a letter read during these hearings: "I have no hesitation in saying that it (water-gas) may be used with safety both in public buildings and private houses. I should be delighted to substitute this pure and powerful illuminating agent for the gas with which my house in London is at present supplied, although it is used in all the bedrooms."

More than a quarter of a century has since gone by and there are now available for study the results of a considerable, though by no means total, replacement of coal-gas by water-gas during a period of about 20 years (1890-1909). The authors of the present paper have accordingly undertaken a careful inquiry to see how

far the predictions referred to have come true. The problem is of course complicated by the fact that in spite of the legislative permission to manufacture and distribute water-gas, this has by no means wholly displaced coal-gas. The results at hand are therefore not such as we might have obtained if the replacement had been complete. Since 1890 some companies have made only water-gas; others, only coal-gas; many have made a mixture of the two, and some have made both intermittently. Still, the broad fact remains that an increasingly larger amount of the poisonous gas, CO, has been distributed since 1890 than before that date and not only absolutely but relatively to the population. The matter is further complicated by the use of illuminating gas for suicide, a subject which requires, and in the present paper will receive, special consideration and discussion.

One good result of the long and active agitation in Massachusetts was that a State Gas Commission had been provided for in 1885. Another was that in 1888 the Gas Commissioners were required to investigate, keep a record of, and report all deaths (or injuries to health) from gas poisoning within the state. From 1888 onward, therefore, we have for Massachusetts a fairly complete report of fatalities and other consequences of gas poisoning, and one probably far better than is possessed by any other state. It is perhaps the only record of this kind existing anywhere. Fortunately we have also, for the same period, the returns of the Medical Examiners concerning deaths from illuminating gas—a body of experts whose opinions possess expert value.

We have taken for study the *fatalities*, only, from gas poisoning. Of the numerous injuries which do not result fatally we have, and can have, no complete record. Some are reported by the Gas Commissioners, but many are never reported at all and many less striking and seemingly transient effects, such as headache or malaise, are neither heard nor even thought of as due to gas poisoning.

As stated above, we have obtained the records of death from gas poisoning in Massachusetts from two sources, namely, the reports of the Gas Commissioners, and the returns of the Medical Examiners. The former are published in the Commissioners'

Annual Reports, the latter in the *State Registration Reports*. The Gas Commissioners' records we owe to a provision of law already referred to, permitting the use of water-gas, but at the same time requiring all gas companies to return to the Commissioners a written report of any death or injury due to gas distributed by the company in question. On the whole this arrangement has worked out fairly well, although in the early years the Commissioners complained with reason that some deaths were not reported. The Commissioners' records begin with the year 1886 and it is interesting to note that poisoning by illuminating gas did not earn itself a separate place in the classification of deaths reported by the Medical Examiners until that same year. The figures of the latter are also available, therefore, since 1886. For data previous to 1886 we have only Dr. Abbott's valuable paper of 1885.

The table now given (Table A) shows side by side the figures derived from the two independent sources mentioned. These data are for the *calendar* year indicated, and include only deaths from poisoning by illuminating coal-gas and water-gas. Deaths from oil gas or acetylene gas and deaths caused by gas explosions, or from burning by gas, have been excluded.

TABLE A.
DEATHS FROM ILLUMINATING GAS POISONING IN MASSACHUSETTS.
(1886-1909.)

Year Ending Dec. 31	Medical Examiners' Returns	Gas Commissioners' Returns
1886.....	5	0
1887.....	6	0
1888.....	6	0
1889.....	5	2
1890.....	12	10
1891.....	16	14
1892.....	28	18
1893.....	27	25
1894.....	43	33
1895.....	31	26
1896.....	52	51
1897.....	63	58
1898.....	78	77
1899.....	65	65
1900.....	45	46
1901.....	37	37
1902.....	63	62
1903.....	71	72
1904.....	61	59
1905.....	77	72
1906.....	68	71
1907.....	147	145
1908.....	123	115
1909.....	102	99
Totals.....	1,231	1,157

The table shows substantial agreement in the two sets of data, especially in the later years. The Medical Examiners' figures are probably the more accurate.

Some of the salient features of this table are the sharp rise beginning in 1890 from a very low previous level and continuing

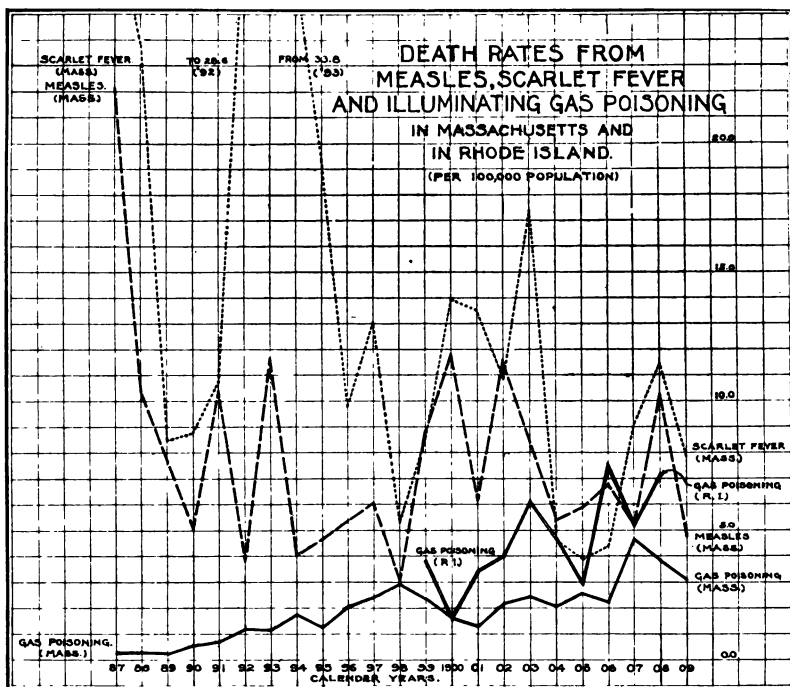


CHART I.

to a high maximum in 1898, with a fall to a lower level in 1901, followed by a rebound which in 1907 reached the highest point in the entire table. From five or six deaths each year before 1890, the number rose to 147 deaths from poisoning by illuminating gas in 1907. Previous to 1885, according to Dr. Abbott, there had been only four deaths during 20 years.

The same fluctuations which appear in this table may be seen in more graphic form, but as death *rates*, in the lowest curve—the heavy black line marked “Gas Poisoning, Mass.”—on Chart I.

Variations corresponding more closely to those in Table A may

also be seen upon Chart 2 in the heavy black line marked "Deaths by Gas Poisoning." It should be noted, however, that the correspondence of these data is not exact in all cases, since the figures in the table above and the curve on Chart 1 represent *calendar* years and rates, while the heavy black line on Chart 2 represents actual deaths and years ending *June 30*. The highest point of the line on Chart 2 thus falls in 1908 and not as on Table A and Chart 1, in 1907.

SOME DEATH RATES FROM SCARLET FEVER, FROM MEASLES, AND
FROM ILLUMINATING GAS IN MASSACHUSETTS
AND IN RHODE ISLAND.

We can best realize the growing importance of illuminating gas as a cause of death by comparing its mortality rate for a period of years with the death rates from such familiar diseases as scarlet fever and measles in States having trustworthy vital statistics. For this purpose we have computed the following statistics for two such States; namely, Massachusetts and Rhode Island:

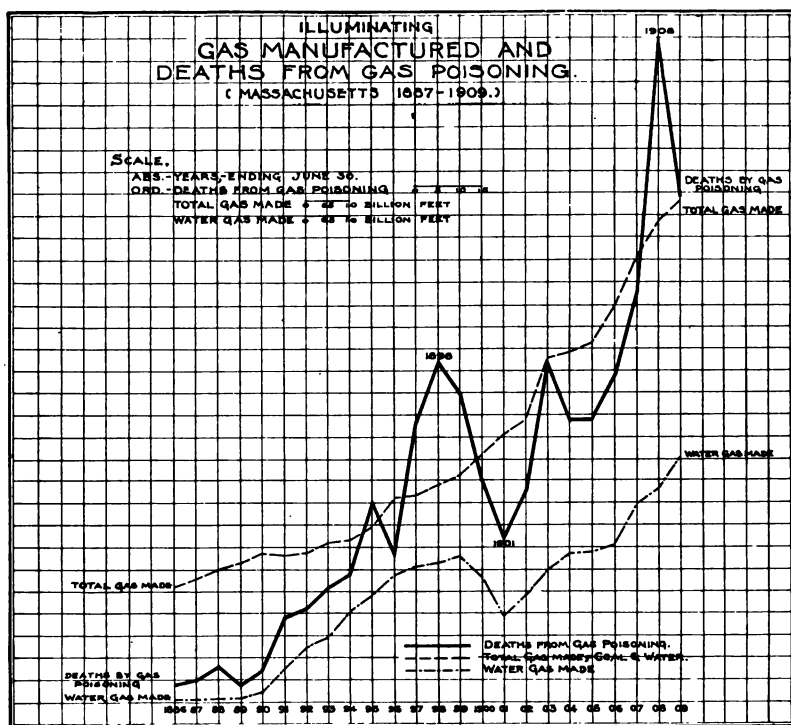
TABLE 1.

DEATH RATES FROM SCARLET FEVER, FROM MEASLES, AND FROM ILLUMINATING GAS IN MASSACHUSETTS
AND IN RHODE ISLAND.

(Per 100,000.)

Calendar Years	Scarlet Fever (Mass.)	Measles (Mass.)	Illuminating Gas (Mass.)	Illuminating Gas (R.I.)
1887.....	28.80	22.08	0.20	
1888.....	21.78	10.33	0.20	
1889.....	8.49	7.85	0.23	
1890.....	8.76	5.00	0.54	
1891.....	10.74	10.31	0.70	
1892.....	28.56	3.76	1.19	
1893.....	33.80	11.52	1.13	
1894.....	26.51	4.00	1.76	
1895.....	10.31	4.63	1.24	
1896.....	9.73	5.35	2.03	
1897.....	13.05	6.03	2.40	
1898.....	5.25	2.05	2.01	
1899.....	8.56	8.78	2.37	
1900.....	13.94	11.77	1.60	1.63
1901.....	13.52	6.03	1.30	3.42
1902.....	10.84	11.53	2.18	4.01
1903.....	17.42	8.44	2.43	6.10
1904.....	4.65	5.39	2.06	4.60
1905.....	3.90	5.89	2.56	1.92
1906.....	4.39	6.76	2.21	7.50
1907.....	9.04	5.18	4.67	5.15
1908.....	11.46	10.27	3.82	7.15
1909.....	7.86	4.77	3.10	

Table 1 shows strikingly how important poisoning by illuminating gas has recently become as a cause of death in Massachusetts and in Rhode Island; and the same facts are displayed graphically by the diagrams on Chart 1 (p. 386). The death rate from the two contagious diseases (scarlet fever and measles) has evidently greatly



declined, while that from illuminating gas poisoning has greatly increased, so much so that the latter bids fair soon to exceed the former.

The death rate from poisoning by illuminating gas was higher in Massachusetts in 1907 than from scarlet fever in 1905 and 1906, while in Rhode Island the death rate from illuminating gas from 1903 to 1907 was at times higher than that in Massachusetts from either scarlet fever or measles. Poisoning by illuminating gas has

evidently become in Massachusetts and in Rhode Island a cause of death nearly as effective as are scarlet fever or measles. It has of late years claimed as many victims as has typhoid fever in some American and many German cities.

AMOUNTS AND KINDS OF ILLUMINATING GAS MANUFACTURED IN
MASSACHUSETTS (1886-1909).

The following table (Table 2), the main features of which appear also on Chart 2, p. 388, shows the amounts of total illuminating gas (coal-gas and water-gas) and of water-gas, manufactured in each year in Massachusetts. The data are derived from the *Annual Reports* of the Gas Commissioners.

TABLE 2.

AMOUNTS OF ILLUMINATING GAS MADE AND OF WATER-GAS, AND DEATHS FROM ILLUMINATING GAS IN
MASSACHUSETTS.

(1886-1909.)

Years Ending June 30	Total Coal- and Water-Gas Made (Million Cu. Ft.)	Water-Gas Made (Million Cu. Ft.)	Deaths from Illuminating Gas
1886.....	2,625	12	...
1887.....	2,765	28	5
1888.....	3,010	47	8
1889.....	3,156	78	4
1890.....	3,346	212	7
1891.....	3,300	777	19
1892.....	3,370	1,231	21
1893.....	3,594	1,467	26
1894.....	3,671	2,022	29
1895.....	3,955	2,413	45
1896.....	4,639	2,876	33
1897.....	4,731	3,090	63
1898.....	4,901	3,107	77
1899.....	5,120	3,265	70
1900.....	5,608	2,881	50
1901.....	6,059	1,961	37
1902.....	6,372	2,400	48
1903.....	7,776	2,989	78
1904.....	7,882	3,335	64
1905.....	8,126	3,373	64
1906.....	8,902	3,539	74
1907.....	9,998	4,471	92
1908.....	10,902	4,862	148
1909.....	11,360	5,518	114

The same facts are depicted graphically upon Chart 2, which deserves and will repay careful study. The apparent discrepancy between these data of deaths and those given on other tables is due to the fact that the "years" end here on June 30, and not as in the other cases on December 31.

A COMPARISON OF MORTALITY FROM ILLUMINATING GAS IN MASSACHUSETTS WITH AMOUNTS AND KINDS OF GAS MANUFACTURED.

From Table 2 and Chart 2 it appears that the total quantity of illuminating gas made in Massachusetts has, on the whole, increased rather steadily, year by year, since 1886. Once only has there been a slight decrease (in 1891) and at times (as in 1896, 1903, 1906, 1907, and 1908) the increase has been very rapid. The curve on Chart 2 shows also on the whole a much more rapid annual increase of output in the later than in the earlier years.

The total quantity of water-gas made shows likewise, on the whole, a great increase since its distribution for illuminating purposes became legally possible in 1890. But the water-gas curve, though approximately parallel to the total gas curve for the years since 1901, was not so before that time. On the contrary, from 1890 to 1896 it was rising much more rapidly; from 1899 it was nearly parallel; and from 1899 to 1901 it declined sharply, whereas the total gas production increased more rapidly than before.

The third line on Chart 2, the heavy black line, shows the deaths, year by year, from illuminating gas in Massachusetts, and, like the other two lines, it shows on the whole a great increase since 1890. It is, however, much less regular in form, and the increase which it shows is much greater than that shown by the other two lines. To the line of total gas production it shows only the most general relation of rapid increase, and that only with numerous and striking exceptions of departure, as in 1896, 1899, 1900, 1901, 1904, 1905, and 1909. If the number of deaths had merely increased *pari passu* with the total amount of gas manufactured, we must have supposed that the poisonous quality of the gas had remained constant and the habits of the consumers unchanged. But this is clearly not the case. The deaths increased very much more rapidly from 1890 to 1898 and from 1901 to 1908 than did the total amount of gas made, while from 1898 to 1901 and from 1903 to 1906 deaths actually decreased while total gas production increased. We are therefore driven to seek some other explanation for the great increase of deaths from illuminating gas than the mere expansion of the industry and the increasing use of gas.

For an explanation we need not look far. If, instead of com-

paring the death curve with the curve of total illuminating gas, we compare it with that of water-gas made, we find a remarkable, though not a perfect, general correspondence. Except in 1896, 1899, 1904, and 1909, this general correspondence is close and striking, both curves rising and falling together, though often at different rates. The general increase in deaths, barring the exceptional years noted, may therefore be readily explained by the general increase in the amount of water-gas made.

From 1898 to 1908 the amount of total gas made had doubled, while the fatalities had not quite done likewise. But while the quantity of total gas made increased about fivefold from 1886 to 1908, the fatalities increased nearly thirty fold. At the same time we find the variations in the amount of water-gas manufactured coinciding much more nearly with the fluctuations in the number of deaths. The remarkable increase of such deaths in 1891 corresponds with the first appearance of any large amount of water-gas. And when the deaths reached a maximum in 1897-99 water-gas had reached a percentage proportion of the total output which it has never equaled either before or since.

In 1900 the New England Gas and Coke Company installed a large coal-gas plant in Everett, and the effect of the introduction of their product into the illuminating gas of the Metropolitan District was to produce an actual decrease for three or four years in the total amount of water-gas manufactured in the state. It is noteworthy and significant that this decrease corresponds closely with the low phase of 1901 in the curve of deaths by gas poisoning. But, as indicated by the diagram, the natural growth of the gas industry soon called for more gas. The check to the production of water-gas in 1901 was only temporary and the increased output since 1901 has been attended by a corresponding increase in deaths from gas poisoning.

In consideration of all these facts we are warranted in concluding that the amount of water-gas produced stands in some close relation to the number of deaths by illuminating gas. This conclusion is justified and confirmed by a comparison of the percentage which water-gas formed of the total gas manufactured, with the deaths per billion feet of total gas produced. If the water-gas is really to

blame, the larger the percentage of water-gas the more dangerous should be each unit of the resultant product. On the other hand, by dividing the deaths from gas poisoning by the total amount of gas made, we should obtain a measure of the poisonous effect of a unit of the total gas. In other words, if the theory that water-gas has been the primary cause of the deaths by gas poisoning is true, we should expect to find some general agreement between the percentage of water-gas to total gas made, and deaths by gas poisoning for each unit, such as a billion feet, of total gas made. That such agreement actually exists appears from Table 3 and its corresponding chart (Chart 3).

TABLE 3.
PERCENTAGE WHICH WATER-GAS MADE WAS OF TOTAL ILLUMINATING GAS
MADE, AND DEATHS PER BILLION CUBIC FEET OF TOTAL
ILLUMINATING GAS MADE (MASSACHUSETTS, 1887-1909).

Year Ending June 30	Percentage of Water-Gas Made to Total Gas Made	Deaths per Billion Cubic Feet of Total Gas Made
1887.....	1.01	1.09
1888.....	1.56	1.17
1889.....	2.43	0.64
1890.....	6.34	2.10
1891.....	22.20	5.76
1892.....	36.60	6.24
1893.....	40.80	7.24
1894.....	55.00	7.90
1895.....	61.00	11.39
1896.....	62.00	7.12
1897.....	65.40	13.31
1898.....	64.60	15.70
1899.....	63.80	13.67
1900.....	51.40	8.92
1901.....	32.30	6.11
1902.....	37.70	7.54
1903.....	38.40	9.78
1904.....	42.30	8.12
1905.....	41.30	7.88
1906.....	39.70	8.31
1907.....	44.70	9.20
1908.....	44.50	13.57
1909.....	48.60	10.05

Table 3, and especially Chart 3, shows a remarkable concordance between the percentage of water-gas manufactured year by year and the corresponding death rate (ratio) from illuminating gas per billion feet of total gas made. In spite of some differences (as, for example, 1896, 1904, 1906, 1908, 1909), it is difficult to avoid the conclusion that the water-gas curve and the death curve stand in the relation of cause and effect.

The agreement between the variations in the percentage of water-gas made and the number of deaths year by year is obviously not absolute, but when we reflect upon the actual conditions under which water-gas is made and distributed, we may well be surprised that the agreement is as close as it is. For illuminating gas is sold in Massachusetts by many companies and under a great

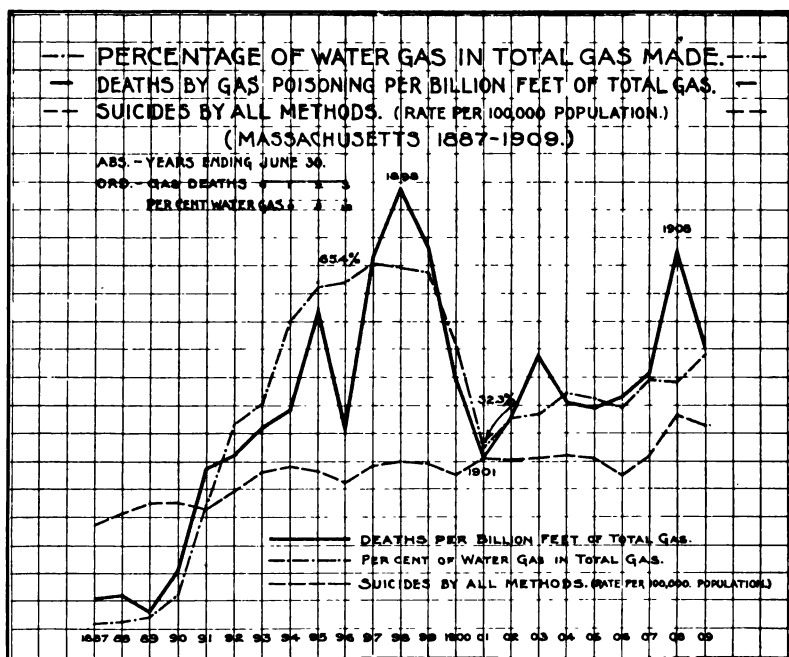


CHART 3.

variety of conditions. Some companies distribute only coal-gas and some only water-gas, but most distribute a mixture of the two. And this mixture may vary widely from time to time in the percentage of the two gases. Again, there is, as we shall learn beyond, a marked seasonal variation in the deaths from illuminating gas, and there is good reason to believe that the mildness or severity of Massachusetts winters may cause annual as well as seasonal variations in the mortality from gas poisoning. These various factors naturally forbid any absolute correspondence between the amount

of water-gas made and the deaths from gas poisoning. When we consider this great variety of circumstances, the wonder is, not that the two curves occasionally differ, but that they run so nearly parallel.

THE USE OF ILLUMINATING GAS IN MASSACHUSETTS FOR PURPOSES OF SUICIDE.

Since 1890 illuminating gas has been gradually discovered by the public to be a convenient and effective means of suicide. Whereas before that time it was very difficult to commit suicide

TABLE B.
DEATHS FROM ILLUMINATING GAS POISONING (MASSACHUSETTS, 1886-1900).
(Medical Examiners' Returns.)

Years Ending June 30	Accidental Deaths	Suicidal Deaths	Total Deaths
1886*	1	1	2
1887	4	1	5
1888	7	1	8
1889	2	2	4
1890	5	2	7
1891	18	1	19
1892	9	12	21
1893	7	9	16
1894	14	15	29
1895	28	17	45
1896	20	13	33
1897	47	16	63
1898	48	29	77
1899	35	35	70
1900	35	15	50
1901	11	26	37
1902	9	39	48
1903	47	30	77
1904	29	35	64
1905	41	23	64
1906	35	39	74
1907	41	51	92
1908	55	93	148
1909	43	71	114
1900†	23	31	54
Totals	624	607	1,231

* First six months.

† Second six months.

by the use of illuminating gas, and probably very few would-be suicides resorted to its use, it has come of late years to be one of the easiest and surest agents of self-destruction. The reports of the Medical Examiners contain ample evidence of this fact.

Table B, prepared by us from the returns of the Medical

Examiners, shows not only the use, but the increasing use, of illuminating gas for purposes of suicide. At the same time this table is a sufficient answer to those who have the assurance to proclaim that, excepting as it is used by suicides, water-gas is no more dangerous to life than is coal-gas.

Of the 1,231 deaths by gas poisoning reported by the Medical Examiners in the years 1886-1909, 607, or 49.4 per cent, were

TABLE 4.

DEATH RATES FROM POISONING BY ILLUMINATING GAS AND FROM ACCIDENTAL AND FROM SUICIDAL
POISONING BY ILLUMINATING GAS, (MASSACHUSETTS, 1887-1909).
(Medical Examiners' Returns.)

Year Ending June 30	Gas Deaths (Totals)	Gas Accidents	Gas Suicides
1887.....	0.251	0.19	0.5
1888.....	0.381	0.33	0.05
1889.....	0.180	0.09	0.09
1890.....	0.31	0.22	0.09
1891.....	0.831	0.79	0.04
1892.....	0.690	0.33	0.51
1893.....	1.034	0.71	0.38
1894.....	1.184	0.57	0.61
1895.....	1.804	1.12	0.68
1896.....	1.129	0.78	0.51
1897.....	2.40	1.79	1.61
1898.....	2.87	1.79	1.08
1899.....	2.55	1.28	1.27
1900.....	1.78	1.25	0.54
1901.....	1.30	0.39	0.91
1902.....	1.66	0.31	1.35
1903.....	2.63	1.61	1.03
1904.....	2.16	0.98	1.18
1905.....	2.13	1.36	0.77
1906.....	2.41	1.14	1.27
1907.....	2.92	1.30	1.62
1908.....	4.60	1.71	2.89
1909.....	3.46	1.31	2.16

reported by them to be suicides and the remainder accidental deaths. Table B gives these data in detail for the separate years.

We have also computed, for the same period, the death rates from illuminating gas and those by illuminating gas from accidental sources and from suicidal sources, as reported by the Medical Examiners (Table 4 and Chart 4). It is hardly necessary to repeat that these, while obviously open to the objection that they represent merely the opinion of the Medical Examiners, are the best data we have and are probably on the whole not far wrong.

It may, of course, be urged that it is often difficult even for expert medical examiners to discover whether or not a particular

death was suicidal or accidental. But even if this be granted and if some deaths reported as accidents were really suicides, the reverse may likewise be true, and there is no good reason to doubt that in a large percentage of cases the Medical Examiners' returns are correct. If any reasonable doubt could exist as to the fact that many accidental deaths do occur from poisoning by illuminating

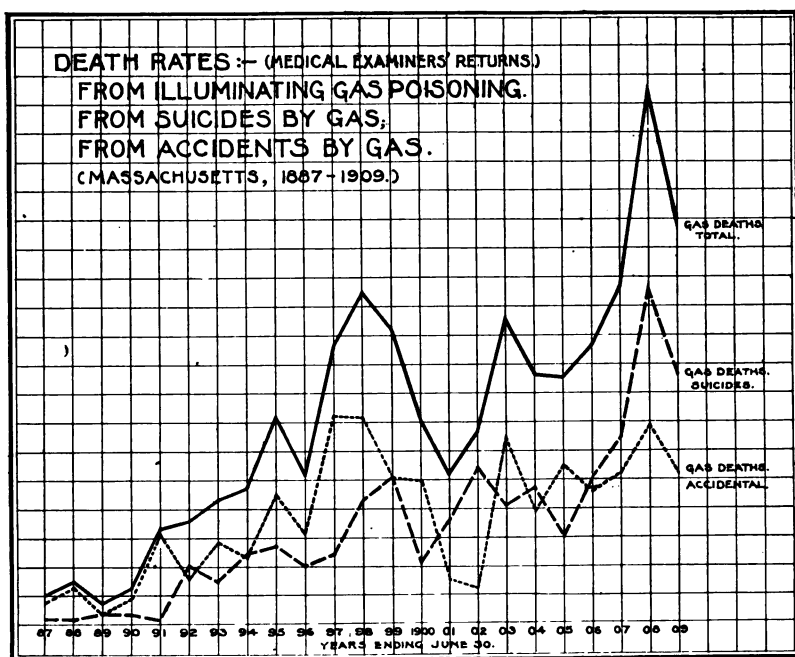


CHART 4.

gas it would be dissipated by an examination of the data shown on the following table (Table 5) and its corresponding chart (Chart 5).

This table and its corresponding plate shows how sudden was the increase in 1891 of deaths from illuminating gas, an increase much more reasonably explained by increase in accidents than by increase in suicidal use of the new and as yet generally unknown poison, especially when we observe that this increase was accompanied by a decrease in the whole number of suicides for the year. Again, in 1895, with no increase in the whole number of suicides, there was a very large increase in the number of deaths from poison-

ing by illuminating gas; in 1904, while the whole number of suicides was increasing, deaths from illuminating gas decreased; while in 1906 the reverse was the case. Undoubtedly, there is on the whole

TABLE 5.
DEATHS FROM SUICIDE BY ALL METHODS, DEATHS FROM ILLUMINATING GAS, AND POPULATION
(MASSACHUSETTS, 1887-1909).
(Medical Examiners' Returns.)

Year Ending June 30	Suicides by All Methods	Deaths from Illuminating Gas	Population of the State
1887.....	152	5	2,238,043
1888.....	175	8	
1889.....	196	4	
1890.....	202	7	
1891.....	194	19	2,500,183
1892.....	231	21	
1893.....	270	26	
1894.....	284	29	
1895.....	282	45	
1896.....	269	33	2,805,343
1897.....	304	63	
1898.....	321	77	
1899.....	323	70	
1900.....	312	50	
1901.....	347	37	3,003,680
1902.....	350	48	
1903.....	358	77	
1904.....	360	64	
1905.....	366	64	
1906.....	338	74	
1907.....	390	92	
1908.....	494	148	
1909.....	476	114	

a striking correspondence in the forms of the two curves, such as ought to exist when we remember that (as shown in Table B) about one-half of all the deaths in the lower line are an important factor in the upper.

A STUDY OF THE SEASONAL DISTRIBUTION OF DEATHS FROM ILLUMINATING GAS IN MASSACHUSETTS.

We had not been studying the general subject of illuminating gas poisoning very long before it became plain that such poisoning bears a close relation to the seasons. And this relation proved to be almost precisely what might have been anticipated. Deaths from illuminating gas are comparatively few in summer and comparatively many in winter, as is shown by the first column in the following table, and by the heavy black line on the corresponding chart

(Chart 6) based upon it. The reason is, of course, because in summer, with open windows, short nights, and outdoor life, people in Massachusetts are much less exposed to gas poisoning than in winter, when they are housed most of the time, often in apartments

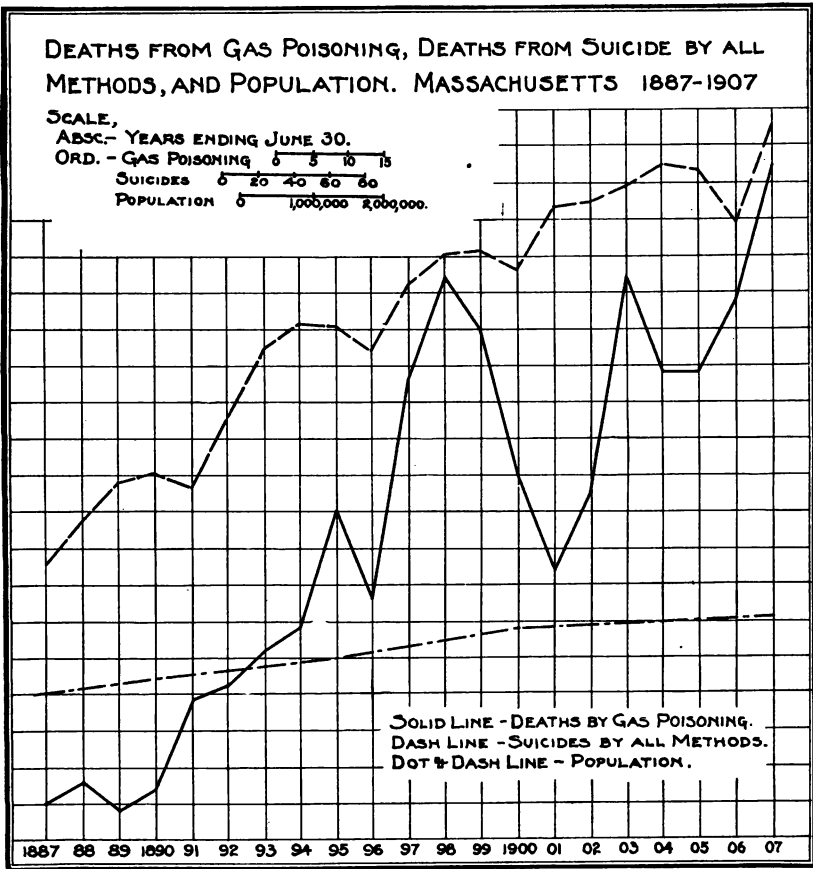


CHART 5.

pipied for gas and having little or no ventilation. Similar considerations probably make gas poisoning also largely a matter of latitude—northern cities suffering more from gas poisoning than southern cities—and likewise produce annual variations according as the winters are mild or severe.

This table and the corresponding chart (Chart 6) disclose many interesting and important details. December stands out as the month of most deaths, and December is one of the months of shortest days and longest nights as well as of lowest average temperature. It is therefore one of the times of greatest use of gas, of most indoor life, and of least ventilation by open doors and

TABLE 6.

SEASONAL DISTRIBUTION OF DEATHS FROM ILLUMINATING GAS, OF DEATHS BY ACCIDENT FROM ILLUMINATING GAS, OF DEATHS BY SUICIDE FROM ILLUMINATING GAS, AND OF SUICIDES BY ALL METHODS (MASSACHUSETTS, 1886-1900).
(Medical Examiners' Returns.)

Month	Total Deaths from Illuminating Gas	Accidental Deaths from Illuminating Gas	Suicidal Deaths from Illuminating Gas	Suicides by All Methods
January.....	106	73	33	568
February.....	97	49	48	462
March.....	106	59	47	597
April.....	116	51	65	749
May.....	90	36	54	686
June.....	67	30	37	647
July.....	57	20	37	634
August.....	64	23	41	603
September.....	92	34	58	611
October.....	144	77	67	655
November.....	143	80	63	594
December.....	149	92	57	541

windows. It is not surprising that these conditions are correlated with the highest mortality from poisoning by illuminating gas. What is remarkable is that the deaths from this source were almost equally numerous in October and November, although the days are then longer, the average temperature considerably higher, and the possibility of comfortable sleeping with more open windows is much greater; while January, which in length of day and temperature closely resembles December, shows fewer deaths than does December from illuminating gas.

July, as might be expected, shows the smallest number of deaths (57), June (67) and August (64) more, and each about the same number, while September yields an increase of more than 40 per cent over June and over August. These facts are not surprising when we reflect upon the cooler and longer nights of June and August over those of July, and the much cooler nights—often with frosts—of September over those of June and of August. But beginning with October there is no great difference in the deaths

by months until we come to January, when in spite of very cold weather and very short days we find a marked decrease of deaths from poisoning by illuminating gas, the deaths for January, February, March, April, and May differing astonishingly little.

We are aided in explaining these various figures by the fact that April and October are the months of most numerous suicides, not

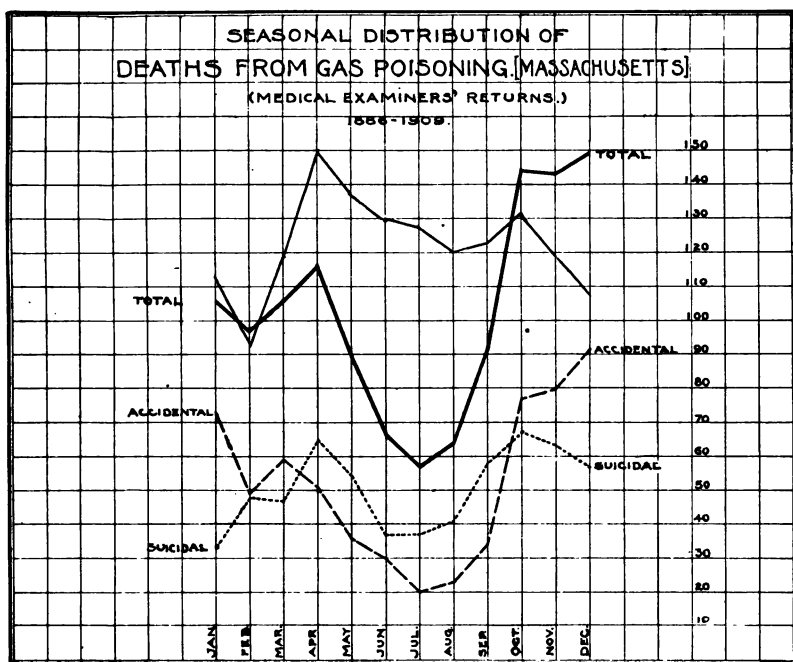


CHART 6.

only by all methods (as shown by the last column in Table 6 and by the corresponding, thin, solid line, without legend, on Chart 6), but also by illuminating gas; so that the curve of total deaths by illuminating gas is necessarily quite different from what it would be if it represented only those deaths due to accident, and if accidents were solely due to considerations correlated with the movement of the seasons—such as temperature and length of days—and effective ventilation. We find here, readily enough, a satisfactory explanation of the large number of total deaths in October (144) and November

(143) as compared with December (149) when the deaths from suicide (both by all methods and by gas) were passing during these months from a maximum to a much lower level. The fact appears to be that while the accidental gas deaths were increasing during this quarter (as appears in Table 6 and Chart 6 and as would be required by theory) the suicidal gas deaths were declining almost *pari passu*; so that a remarkably even and high total of deaths from illuminating gas was maintained during this last quarter of the year.

In the next quarter (January-March) the gas suicides were considerably fewer, as were also the deaths from accidental gas poisoning, and very likely the same explanation holds good of both these causes of death; namely, that conditions had now become comparatively endurable, those that were absolutely intolerable having already destroyed their victims or having been changed for the better. The high number of total deaths in April appears to be chiefly due to the excess of suicides in general characteristic of that month, as does also the lower but still large number in May, when, as required by theory, the seasonal conditions do not greatly favor accidental gas poisonings and when, in fact—as shown by our figures—such poisonings are comparatively few.

It is also interesting to note, in passing, that upon Table 6, and excepting in the first quarter, a close correspondence is shown between the frequency of suicides by all methods and those by illuminating gas.

THE RELATION OF CERTAIN COMBUSTION PRODUCTS OF ILLUMINATING GAS TO THE PUBLIC HEALTH.

The principal combustion products of illuminating gas are carbonic acid (CO_2), water (H_2O), light, and heat. Small, but not insignificant amounts of ammonia, sulfurous acid, soot, and other substances are also produced.

Carbonic acid, an inevitable product of all complete combustion of carbon compounds, while not a desirable addition to the atmosphere of a dwelling, a store, or a workshop, is probably, unless present in very large quantities, of but little consequence from the standpoint of health or comfort.

Water vapor, which is also copiously and inevitably produced in the ordinary combustion of illuminating gas, is probably of more importance than is carbonic acid to health and comfort. Evidence of its abundant presence may often be seen in the water upon the windows of shops, of stores, or of living rooms, upon which it condenses freely and runs down, sometimes almost in streams. The high humidity to which this testifies is often prejudicial to the comfort, and probably also to the health or working capacity, of the inmates.

The light produced by illuminating gas varies widely in amount and composition. The old-fashioned coal-gas gave an agreeable and apparently powerful yellowish light, and when those who were accustomed to it began to be served with water-gas, many found the latter bluish and less efficiently luminous. Much here depends, no doubt, upon the special form of burner, or "tip" employed, but after all is said and done there are many—of whom the senior author is one—who, having lived with both kinds of gas (and with many kinds of mixtures of the two) would gladly go back to the old-fashioned coal-gas at double the present cost of gas, not only because of its greater safety, but also because of its greater and more agreeable illuminating effects.

As to the question of heat produced by combustion—a question of great economic importance for those using gas as a source of power, or for cooking or heating purposes, and of much hygienic significance for persons occupying rooms lighted by gas, it should be said that water-gas is not greatly superior to coal-gas, while, since much heat is produced by the combustion of either gas, their hygienic effects in this particular are probably not very different. Electric lighting (although open to other objections) is vastly preferable to gas lighting on the score of heat production and that of objectionable chemical products.

Among the less abundant products of the combustion of illuminating gas is sulfurous acid. Most coals used in the manufacture of gas—and hence known as "gas coals"—contain a small percentage of sulfur, some of which appears in illuminating gas as hydrogen sulfide and some as bisulfide of carbon, or other sulfur compounds. These, when burned, form sulfurous acid, an irritating and poison-

ous gas. Most of the sulfur compounds in illuminating gas are, however, removed by processes of purification during manufacture, but owing to the difficulty of complete removal, 20 grains of sulfur in every hundred cubic feet have generally been allowed by law to remain in the gas distributed to the public. The 20-grain limit has prevailed in Great Britain for about half a century, and was apparently copied into American statutes when legal regulation of the quality of illuminating gas was first undertaken—in Massachusetts, for example, in 1861. And until quite recently no objection to this legal limit has been raised by the gas manufacturers or by anyone else. A few years ago, however, the London gas companies sought to have this sulfur regulation removed, claiming that because the best gas coals are now scarce, it is much more difficult than formerly to procure coals low in sulfur, so that processes for the removal of sulfur have become more costly and really burdensome to the industry of gas manufacture. And after protracted hearings with the taking of much testimony the sulfur restrictions were, in fact, removed in England. A little later gas manufacturers in the United States and in Canada came forward with a similar demand, and in Massachusetts the legal limit for sulfur has now been raised from 20 grains to 30 grains per 100 cubic feet of gas. A complete discussion of the whole subject of the relation of the combustion products of sulfur compounds in illuminating gas to the public health would require a monograph. Suffice it to say that the testimony taken by the British Commission having the matter in charge, and by the Gas Commissioners of Massachusetts (not to mention other authorities) was voluminous, instructive, and important, and deserving of careful attention. It is the opinion of the authors of the present paper that the British authorities were not sufficiently considerate of the public health aspects of the subject when they allowed all restrictions upon the sulfur content of illuminating gas to be removed, and that the Massachusetts Gas and Electric Light Commissioners acted more wisely when they declined to follow the British example and merely relaxed somewhat the severity of the legal requirements regarding sulfur.

Illuminating gas is required by law in Massachusetts (and in many other places) to be free from ammonia as well as from

sulfuretted hydrogen, but this is more because of injury to fixtures than because of danger to health.

THE PREVENTION OF POISONING BY ILLUMINATING GAS.

The question naturally arises, What can be done for the protection of the public health against poisoning by illuminating gas, which as a cause of sickness and death now almost equals in Massachusetts and Rhode Island some of the dreaded infectious and contagious diseases? We must admit at the outset that about one-half of the recorded deaths from this source are voluntary or suicidal, but while recognizing this fact we have no right to dismiss it as irrelevant to the present discussion. The State seeks, as far as possible, to prevent suicide, by laws, for example, regulating the sale of other poisons and of firearms, and may well regard with concern the general distribution to the public of a dangerous gas readily available for self-destruction.

Even more serious are the public consequences of the widespread distribution to sick and well for industrial and domestic purposes of a dangerous and highly poisonous substance, insidious in its mode of operation, quickly harmful in its effects, and delivered under such pressure that leaks are frequent. Those who have read and reflected upon the facts given in the preceding sections will hardly need to be told how prejudicial to the public health even small leaks of illuminating gas must be, especially if long continued, while the leakage or escape of larger amounts is well known to be often fatal to those exposed. The simplest and most natural remedy for these evils would be, of course, to return to the former practice of making and distributing only coal-gas instead of water-gas or a mixture of the two. But here, as so often in public health problems, a balance must be struck between industrial advantages accruing to the public in less cost, and some saving of life and health. If the industrial, economic, or efficiency gain is very great, it may justify some increase of danger to life and health. But if it is not very great, then life and health have the prior claim. In the present case it is not claimed that water-gas in Massachusetts or Rhode Island is, as a rule, much if any cheaper to manufacture than is coal-gas, but that it is very convenient to produce because

more quickly made when needed. The claims of the advocates of water-gas in 1884 that this gas would furnish 24 candles of light against the 16 candles of the old-fashioned coal-gas do not appear to have been substantiated, since most of the gas now distributed in Massachusetts equals—according to the State Inspector—only about 18 candles. The price of gas to the consumer has, however, fallen greatly since 1884, and this decrease in cost, as far as it is due to the use of water-gas, must be balanced against the damage done to the public health by the loss of more than 1,200 lives and an unknown amount of less obvious injury to life and health.

Undoubtedly a mixture of coal-gas and water-gas, such as is often distributed today, is less dangerous than is water-gas alone, but this appears to be merely because the dangerous constituent, carbonic oxide, so abundant in water-gas, is diluted by the process of mixture; and up to a certain point, the greater the dilution, the less the danger. We know from experience that when carbonic oxide forms only about 6 per cent of illuminating gas very little danger exists. We also know from experience that 20-30 per cent of carbonic oxide means danger. But whether 10 per cent or perhaps 12 per cent might be allowed without much danger, we do not yet know. It should, however, be possible to determine by experiment the minimum amount safely allowable.

Meantime, in view of the appalling loss of more than 1,200 lives which has occurred in Massachusetts since the 10 per cent restriction was removed, it seems not unfair or unreasonable to demand a return to the 10 per cent limit until such time as evidence shall be forthcoming that a higher percentage will properly safeguard the public health.

APPENDIX.

A DIGEST OF LEGISLATION IN MASSACHUSETTS BEARING UPON THE RELATION OF ILLUMINATING GAS TO PUBLIC HEALTH.

FRANZ SCHNEIDER, J. R.

Acts of 1861, chap. 168. *An Act for the Inspection of Gas Meters, the Protection of Gas Consumers, and the Protection and Regulation of Gas Light Companies.*

SECTION 1. Appointment of inspector. His duties. SEC. 2. His tenure of office; compensation; oath of office; bonds; etc. SEC. 3. List of gas companies. Inspector's salary, how paid. Delinquent companies, proceedings against. SEC. 4.

Appointment of deputies. Qualifications, disabilities, fees, etc. SEC. 5. Standard of measure. SEC. 6. Sealing of meters. SEC. 7. Apparatus. SEC. 8. Test gas-holders. Test meters. Examination, proving and stamping. Record of meters. SEC. 9. Expense of testing meters. SEC. 10. Standard of gas. Twelve candle-power minimum. "Whenever requested by the Mayor and Aldermen of any city or the Selectmen of any town, the inspector shall report to them whether the gas supplied is of the legal standard, and also whether it is sufficiently well purified from sulphuretted hydrogen, ammonia and carbonic acid." SEC. 11. Right of companies to enter premises, etc. SEC. 12. Right to stop gas, etc. SEC. 13. Penalty for injury, trespass, etc. SEC. 14. Fraudulent use of gas. SEC. 15. "This act shall apply to all companies which manufacture gas for sale, and shall take effect July first, eighteen hundred and sixty-one. . . . Approved, April 10, 1861."

It was under this act that Hon. John A. Andrew, the famous "War" Governor of Massachusetts appointed as the first State Inspector of Gas Meters and Gas, the late Professor William Barton Rogers, founder and first president of the Massachusetts Institute of Technology. No further legislation of a sanitary sort appears to have been enacted until 1880.

* * * * *

Acts of 1880, chap. 230. *An Act in Addition to "An Act for the Inspection of Gas Meters, the Protection of Gas Consumers, and the Protection and Regulation of Gas Light Companies."*

SECTION 1. Assistant inspector of meters to be appointed by the Governor, etc. SEC. 2. Inspector and assistant to be paid traveling expenses. SEC. 3. Meters to be sealed. Penalty. SEC. 4. Company to provide a suitable room containing a disc photometer. SEC. 5. Inspection of Gas. (See Pub. Stat. 61 [14].) Read "provided" for "but" in sentence 1; "whenever" for "when" in sentence 4. Add to sentence 4: "but no fine for any impurities found before the first day of September, eighteen hundred and eighty shall be imposed"; read "whenever" for "when" in sentence 5. SEC. 6. Amendment of Act of 1861, chap. 168 (7). SEC. 7. Repeal of Act of 1861, chap. 168 (6). . . . Approved April 22, 1880.

This act of 1880, chap. 230, was introduced in the House on April 1, 1880, for the Committee on Manufactures and passed to second reading; third reading following on April 6; to be engrossed, April 11. It was introduced into the Senate and passed to second reading, April 13. Third reading was refused April 14; reconsideration was requested April 15; passed to third reading April 19; enacted April 22, 1880. These facts are interesting as showing that there was no serious opposition of any kind to the passage of the bill. A search of the files of the *Boston Transcript* for that period fails also to reveal any special interest in the subject and yet it was Section 5 of this Act of 1880 which, as we shall now see, prevented for the next ten years the legal manufacture and distribution of water gas for illuminating purposes.

* * * * *

Pub. Stat. Mass., Enacted November 19, 1881, to take effect February 1, 1882, Chap. 61. *Of the Inspection of Gas and Gas-Meters.*

SECTION 1. Appointment of inspector and assistant inspector and their terms of office. 1861, 168; 1880, 230. SEC. 2. Salaries, etc. SEC. 3. Bonds. SEC. 4. Inspector and assistant not to be interested in manufacture of gas, etc. SEC. 5.

General duties of inspector and assistant. SEC. 6. Appointment of deputy inspectors. Fees. SEC. 7. Salaries and expenses of inspector and his assistant to be paid into the State Treasury by gas companies. 1861, 168 (3); 1878, 223. SEC. 8. Standard measure for gas. SEC. 9. Apparatus and chemicals provided. SEC. 10. Gas-light companies and vendors of meters to provide test gas-holders and gas-meters, etc. SEC. 11. Meters not to be used unless stamped. SEC. 12. Testing of meters in use. SEC. 13. Gas-light companies to furnish room with photometer. SEC. 14. "The gas of every company supplying more than fifty consumers shall be inspected at least twice a year, and one additional inspection shall be made for every four million cubic feet of gas supplied by each company; but the gas of no company shall be inspected oftener than once a week. All such inspections shall be made by the inspector or his assistant and one-fourth at least of all such inspections shall be made by the inspector. The gas shall be tested for illuminating power by means of a disc photometer, and, during such test, shall be burned from the burner best adapted to it, which is at the same time adapted to domestic use, and at as near the rate of five feet per hour as is practicable. When the gas of any company is found on three consecutive inspections to give less light than fifteen standard English candles, or to contain more than twenty grains of sulphur or ten grains of ammonia per hundred cubic feet of gas, or more than 10 per cent of carbonic oxide, or any sulphuretted hydrogen, a fine of one hundred dollars shall be paid by such company to the city or town supplied by it. When during the test the consumption of gas varies from five feet per hour, or the candle from one hundred and twenty grains per hour, a proportional correction shall be made for the candle power." 1880, 230 (5). SEC. 15. Right of entrance. SEC. 16. Right to stop gas. SEC. 17. Penalty for injury to meter, etc. SEC. 18. For unlawfully using gas. SEC. 19. Companies to which chapter applies.

Under SEC. 14 above, the eight words "or more than 10 per cent of carbonic oxide" entirely prevented the legal distribution of water gas for illuminating purposes in Massachusetts. It was not until 1890 that this restriction was removed.

* * * * *

Acts of 1885, 240 (1). *Gas allowed for heating, cooking, chemical and mechanical purposes. Exemption granted from Pub. Stat., chap. 61, secs. 13 and 14.*

Be it enacted . . . as follows:

SECTION 1. The provisions of SECS. 11, 52 and 75 of chap. 106 of the Pub. Stat. are hereby extended so as to authorize the establishment and operation of corporations for the purpose of making, selling and distributing gas for heating, cooking, chemical and mechanical purposes. Said corporations shall have all the powers and privileges and be subject to all the duties, restrictions and liabilities set forth in all general laws which now or hereafter may be in force relating to gaslight companies; provided, however, that secs. 13 and 14 of chap. 61 of the Public Statutes shall not apply to gas made and used exclusively for heating, cooking, chemical and mechanical purposes. SEC. 2. Such gas shall not be used for domestic purposes unless connected with a chimney or flue having direct connection with the open air; provided, however, that nothing in this section shall be construed to apply to illuminating gas as defined by the provisions of sec. 14, chap. 61 of the Pub. Stat. Any violation of this section shall be punished by a fine not exceeding twenty dollars for each and every offense. SEC. 3. This act shall take effect upon its passage. . . . Approved May 15, 1885.

Acts of 1885, chap. 31. *An Act to Establish a Board of Gas Commissioners.*

SECTION 1. Board of Gas Commissioners to be appointed by Governor. Also clerk. SEC. 2. Term of office (3 yrs.). Vacancies. SEC. 3. Commissioners forbidden to be interested in sale of gas. SEC. 4. Salaries. SEC. 5. Incidental expenses. SEC. 6. Annual expenses to be assessed from gas companies. SEC. 7. Gas companies to make annual sworn returns. SEC. 8. Board to have supervision of corporations making and selling gas, etc. SEC. 9. Investigation of complaints, as to quality of gas. SEC. 10. Second gas company not to dig up streets without permission. SEC. 11. Purity of gas. May investigate and recommend regulations to the legislature. SEC. 12. Attorney-general must be notified if company neglects to comply with orders. SEC. 13. Provisions may be enforced in equity. SEC. 14. Annual report to legislature. SEC. 15. Gas inspectors to render assistance, etc. SEC. 16. Gas companies may appeal to Board in case of grievance. SEC. 18. Approved June 11, 1885.

* * * * *

Acts of 1886, chap. 250.

Amends Pub. Stat., chap. 61, sec. 14, to read six million cubic feet instead of four million cubic feet.

* * * * *

Acts of 1888, chap. 350. *An Act in Addition to "An Act to Establish a Board of Gas Commissioners."*

SECTION 1. Fixing price. SEC. 2. All companies and individuals engaged in the business of manufacturing and selling gas and electricity for light or fuel shall make a written report within twenty-four hours to the Board of Gas Commissioners of every accident caused by the gas or electricity manufactured or supplied by them, whereby an employer or any other person shall suffer bodily injury or loss of life or be rendered insensible, stating the time, place and circumstances of the accident, and such other facts in relation thereto as the Board may require; and the Board shall present in its annual report an abstract of all such cases. The Board shall personally investigate all cases which it may deem to require investigation. SEC. 3. This act shall take effect on the 30th day of June, 1888. . . . Approved May 17, 1888.

* * * * *

Acts of 1888, chap. 428. *An Act Authorizing the Gas Commissioners to License Certain Gas Companies to Make and Sell Water Gas for Illuminating Purposes.*

SECTION 1. "The Board of Gas Commissioners is hereby authorized to license any company now authorized to make gas for illuminating purposes to make and sell water gas for illuminating purposes containing any percentage of carbonic oxide that said Board may determine: *provided* that such Board shall be of opinion and shall certify in any license granted by them that in their opinion the gas so authorized can be used with safety for such purposes, and after receiving such license said company shall be exempt from any penalty or prohibition provided in sec. 14, of chap. 61 of Pub. Stat. relating to carbonic oxide provided the percentage of carbonic oxide shall not exceed the limit allowed by said Board. SEC. 2. Any company which shall under the provisions of the first section of this act be licensed to make and sell water gas for illuminating purposes containing an excess of 10 per cent of carbonic oxide

shall furnish to every actual consumer a copy of the Gas Commissioners' license which shall contain a statement of the percentage of carbonic oxide such gas contains as near as can be ascertained. And no company so licensed shall charge more for water gas in any locality than is charged in that locality by any company furnishing gas therein when the manufacture and sale of such water gas is so licensed." SEC. 3. This act shall take effect upon its passage. . . . Approved May 29, 1888.

* * * * *

Acts of 1890, chap. 252. *An Act Removing Restrictions from the Manufacture and Sale of Water Gas for Illuminating Purposes.*

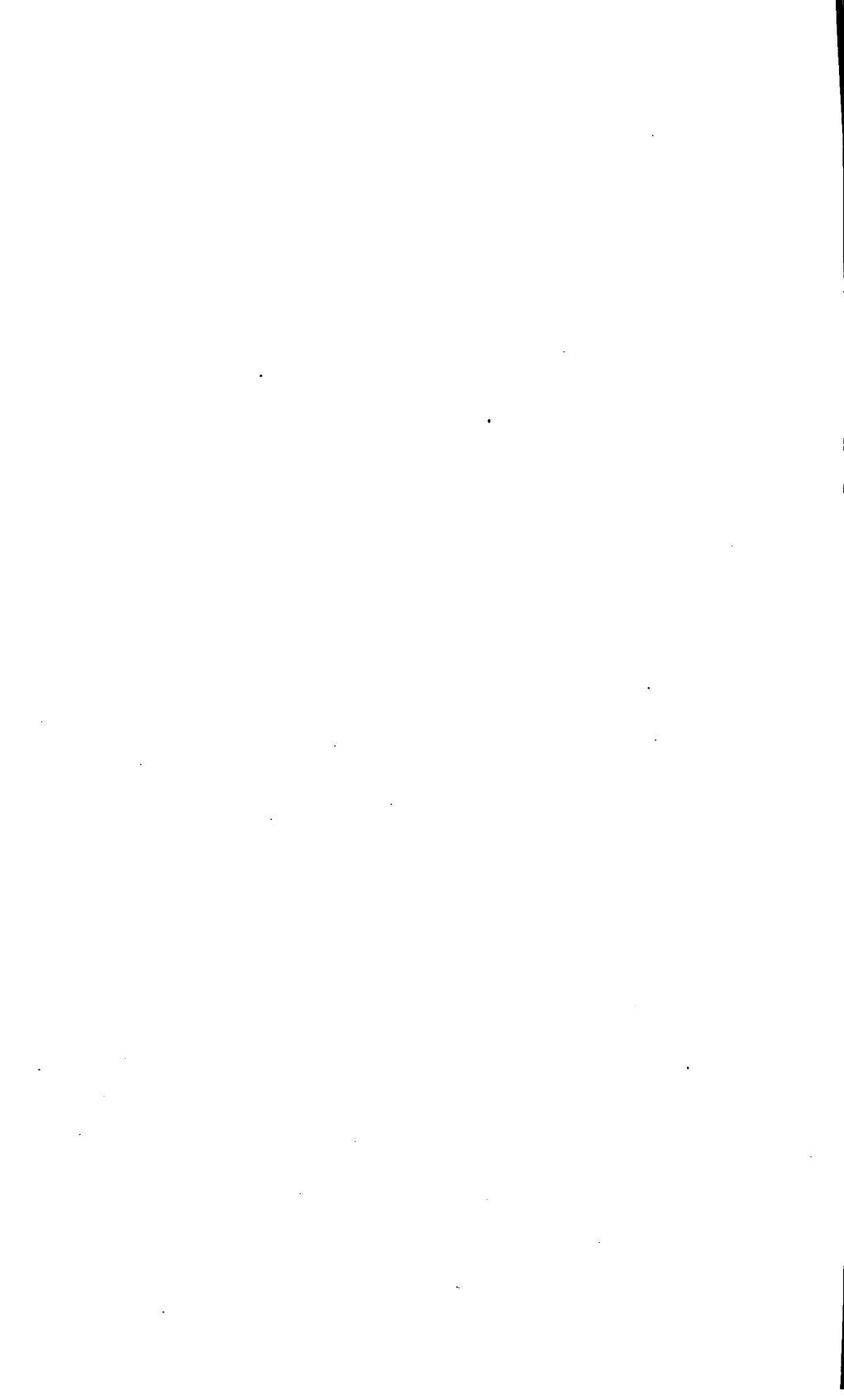
SECTION 1. Sec. 14, chap. 61, Pub. Stat. relating to inspection of gas is hereby amended by striking out in the fifteenth line the words "or more than 10 per cent of carbonic oxide," so that the last two clauses of said section as amended shall read as follows: "When the gas of any company is found on three consecutive inspections to give less light than fifteen standard English candles, or to contain more than twenty grains of sulphur or ten grains of ammonia per hundred cubic feet of gas, or any sulphuretted hydrogen, a fine of one hundred dollars shall be paid by such company to the city or town supplied by it. When during the test the consumption of gas varies from five feet per hour, or the candle from one hundred and twenty grains per hour, a proportionate correction shall be made for the candle power. SEC. 2. Chap. 428, Acts of 1888, authorizing Gas Commissioners to license gas companies to make and sell water gas for illuminating purposes is hereby repealed. SEC. 3. This act shall take effect upon its passage. . . . Approved April 30, 1890.

* * * * *

Acts of 1892, chap. 67. Raises candle power standard required from 15 to 16 standard candles.

Acts of 1902, chap. 228. (1) Transfers powers and duties of inspector of gas meters, etc., to Gas and Electric Light Commissioners.

Acts of 1903, chap. 464. Amends section providing for inspection and testing of illuminating gas. Modifies methods but not substances to be tested for.



REPRINTED FROM

The

Journal of Infectious Diseases

FOUNDED BY THE MEMORIAL INSTITUTE FOR INFECTIOUS DISEASES

VOL. 8

April 12, 1911

No. 3

INVESTIGATIONS ON THE PURIFICATION OF BOSTON SEWAGE.*

C.-E. A. WINSLOW AND EARLE B. PHELPS.

(From the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology.)

I. PURIFICATION OF BOSTON SEWAGE ON TRICKLING FILTERS (1907-9).

1. *Description of experiments.*—Earlier investigations carried out at the Sewage Experiment Station of the Massachusetts Institute of Technology (Winslow and Phelps, 1906; Winslow and Phelps, 1907) have led to the conclusion that sewage of the character of Boston sewage could be purified most satisfactorily and economically by treatment on trickling beds without further preliminary treatment than that afforded by screens and grit chambers. The beds used in the previous work were 8 feet in depth and the filling material was $1\frac{1}{2}$ -2-inch broken stone. The studies now reported were mainly directed toward the solution of the question of the best depth for trickling beds to treat Boston sewage and the best size of filling material to use in their construction.

The experimental filters were situated at the Albany Street Experiment Station and the applied sewage was drawn from the

* Received for publication January 3, 1911.

9-foot trunk sewer of the Boston Main Drainage Works at a point where there is a flow of some 50 million gallons a day from a contributing population of 250,000 (Winslow and Phelps, 1906). It was raised by a 4×6 Warren duplex pump, and roughly settled by passage through a grit chamber, 19 inches in diameter and 16 inches deep, fitted with a screen having bars $\frac{1}{2}$ inch apart, to a small tank on the ground floor. The sewage was then lifted without further sedimentation by a $\frac{3}{4}$ -inch centrifugal pump to a distributing tank in the upper story of the tank house. This distributing tank was 6×4 feet in plan and 3 feet deep, and a constant head was maintained in it by wasting over a 36-inch weir at one end. From the opposite end of the tank, sewage flowed to the trickling filters through two brass orifices whose vertical positions were adjustable. No sludge was removed from this tank, any sludge which temporarily settled out being stirred up and allowed to pass to the filters. The liquid applied to the beds was therefore crude sewage except for the action of the small detritus tank described above and except for the comminution which always attends the passage of sewage through small pipes and pumps.

The filters themselves were outside the tank house in the open air. The total surface was 200 square feet, divided into four units, each 5×10 feet. For a foundation 4×4 spruce sills were buried in the ground and upon them a 1-inch hemlock floor was laid and covered with Portland cement mortar. Half-inch radiating channels in the concrete directed the flow of the effluent to 1½-inch outlet pipes. The sides of the filters were of spruce planks with $\frac{1}{2}$ -2-inch openings between them, supported by 4×4-inch studs braced on all sides and tied at the tops by $\frac{1}{2}$ -inch iron rods.

The first of the four filter units (A) was filled to a depth of 7 feet with 1-1½-inch broken stone resting on about 1 foot of 3-12-inch boulders. The second (B) was of the same construction except that the stone was coarser, 1½-2 inches in diameter. This stone was the same that had been used for two years in the previous experiments (Winslow and Phelps, 1907). The third filter (C) was just like B in construction, but only 5 feet deep instead of 8. Filter D was at first constructed like C except that the surface foot was of finer material, $\frac{1}{2}$ -inch stone. This fine filter clogged so badly, how-

ever, that after four months' use it was dug out and replaced by a bed built of brick somewhat after the fashion of a Dibdin slate bed. Ordinary building bricks, approximately $2 \times 4 \times 8$ inches, were laid so as to overlap as little as possible on the corners, forming a bed with nearly half its total capacity as open space.

The effluent from the four filter units passed by $1\frac{1}{2}$ -inch pipes into the tank house and there the effluents from A and B and from C and D were mixed and sedimented in two secondary sedimentation tanks for the removal of suspended solids. Each tank was a simple inverted cone with a diameter of 7 feet 2 inches at the top and a depth of 4 feet. At the center of each tank a vertical funnel 6 inches in diameter extended to within 15 inches of the bottom. The filter effluents were discharged into the top of this funnel and passed out into the tank through lateral openings near the bottom. They ascended with decreasing velocity and overflowed at four points through skimming-troughs at the surface. The storage period in the tanks was about 2 hours.

Sewage was applied to Filters A and B from a single gravity distributor of the type devised at the experiment station and described in earlier publications (Winslow and Phelps, 1907). The sewage was conducted to the center of the double bed in a 3-inch wooden trough from which it dropped through a $\frac{3}{4}$ -inch opening in the bottom of the trough on to a concave disc from which it splashed upward and outward. The splash cup was 3 inches in diameter and its concavity had a 6-inch radius. It was supported 1 foot above the surface of the bed and 3 feet below the bottom of the trough. Filters C and D were dosed from below with a Columbus sprinkler nozzle having a $\frac{9}{16}$ -inch orifice and a 90° cone above for spreading the spray. This nozzle was dosed intermittently from a siphon tank under a head varying between 4 feet and 3 feet and taking $1\frac{1}{2}$ minutes to discharge and 2 minutes to fill.

Samples of sewage and effluents were collected day and night at intervals of three hours, chloroformed, mixed, and analyzed at the end of the week. Chemical determinations were made by the standard methods of the American Public Health Association, modified in respect to nitrate and free ammonia as discussed in our previous paper (Winslow and Phelps, 1907). Daily samples of all

effluents were tested for stability by the methylene blue test and the results are expressed in terms of "relative stability" as defined in an earlier paper (Phelps, 1909).

2. *General results of trickling filtration.*—All four filter units were operated during the course of the experiments, October, 1907, to May, 1909, at a rate of about 1,500,000 gallons per acre per day. The actual net figures as determined by ratings of the mixed effluents from each pair were 1,280,000 gallons per acre per day for Filters A and B and 1,320,000 gallons per acre per day for Filters C and D.

In regard to the practical working of the beds there were important differences corresponding to the size of the filling material. While Filter D was operated on the first plan, with a 1-foot layer of half-inch material on the surface, it clogged badly. It is clear that half-inch material cannot be used for the treatment of crude sewage like that at Boston. A ($1-1\frac{1}{2}$ -inch stone) and B and C ($1\frac{1}{2}$ -2-inch stone) all clogged somewhat during the first winter, but the clogging of A was the most serious. On four occasions it was necessary to rake up a few inches of stone from Filter A to the corners of the bed, and the same thing was done to B twice. The surface of Filter C on the other hand required no attention. It was evident that the more perfect dosing from the Columbus nozzle was a distinct advantage. After the first winter all the beds cleared up considerably and no material was actually removed from any of them. The surface of Filter A remained more or less clogged, however, and it was evident that filtering material under $1\frac{1}{2}$ inches would not operate successfully with crude Boston sewage.

Since the experiments began in the autumn, there was a long period of ripening before the filters were really doing effective work. The quarterly averages in Table 1 show that none of the effluents had a relative stability over 35 for the first six months of operation. With the warm weather of spring all but Effluent D began to improve, reaching a stability of 50-70, and in the autumn quarter Effluents A and B attained a stability over 80. When the filters were once well ripened good conditions were maintained through the winter and spring of 1909. The free ammonia values show the same relation. For Effluent A the free ammonia averaged 13.4 for

the first three quarters and 6.8 for the last four. For Effluent B the figures were, respectively, 13.0 and 7.9. Nitrites appeared in considerable amounts only in the spring and summer of 1908; and after the nitrite-forming bacteria had established themselves the nitrate-formers began their work. The whole cycle of ripening exactly paralleled that recorded in the experiments of the previous two-year periods (Winslow and Phelps, 1907).

The average results for the sewage, the four trickling effluents and the two sedimentation effluents for the last year of operation, are brought together in Table 2. Quarterly averages for the whole 20 months are given in Table 1; but a fairer idea of the actual working of the process may be gained by excluding the preliminary period of ripening.

It appears from the table that all the filters effected an appreciable though not a large reduction in suspended solids. Whatever reduction did occur may probably be accounted for by storage in the beds, as other experiments have shown that trickling beds do not effect a marked diminution of suspended matter. A distinct change from volatile to fixed solids is evident, however, every effluent showing a considerable reduction in volatile suspended matter and an increase in fixed suspended solids. Organic nitrogen is only slightly reduced as compared with the sewage value but free ammonia shows a reduction of 24 per cent for Filter D, 37 per cent for Filter C, 46 per cent for Filter B, and 54 per cent for Filter A. Nitrites in all the effluents average from 0.5 to 0.8 parts and nitrates from 4.2 for Filter D to 6.6 for Filter B. Oxygen consumed values show for the two best filters, A and B, a reduction of 32 per cent in the total oxygen consumed and 34 per cent in soluble oxygen consumed; as determined in fifteen minutes in the cold, the reduction was about the same for the total oxygen consumed (31 per cent), but distinctly better for the soluble portion (40 per cent). Oxygenation was fairly satisfactory in all the effluents, the average value of 2.2 parts for the crude sewage being increased to from 5.6 to 8.1 parts.

The analytical data show comparatively slight differences, aside from the tests for organic stability. Effluent D has a considerably larger proportion of suspended solids, as would of course be expected from its coarse construction. There are two significant

TABLE I.
ANALYSES OF SEWAGE AND EFFLUENTS, 1907-9. QUARTERLY AVERAGES.

AVERAGE OF MONTHS	Turbidity	Sedi- ment	PARTS PER MILLION										REL- ATIVE STABIL- ITY	TEMP. FAHR.			
			Suspended Solids		Nitrogen as				Oxygen Consumed						Dis- solved Oxygen		
					Organic		Free NH ₃	N.O. ₂	N.O. ₃	30' Boiling		15' Cold					
					Total	Sol.				Total	Sol.	Total				Sol.	
CRUDE SEWAGE.																	
Oct., Nov., Dec., 1907...	246	106	149	85	64	27.0	6.5	2.5	18.0	0.0	0.0	65	47	11.6	7.6	4.0	53
Jan., Feb., Mar., 1908...	203	57	212	152	60	31.7	10.6	3.5	17.6	0.0	0.0	74	48	11.8	7.5	6.1	44
Apr., May, June, 1908...	204	55	171	126	45	38.4	12.7	3.5	18.4	0.0	0.0	68	54	14.1	10.3	1.6	50
July, Aug., Sept., 1908...	183	68	147	98	40	28.8	8.7	4.3	13.8	0.0	0.0	50	42	12.4	8.0	0.0	71
Oct., Nov., Dec., 1908...	262	109	147	98	40	20.9	9.5	5.1	15.2	0.0	0.1	57	41	11.4	8.1	3.1	55
Jan., Feb., Mar., 1909...	300	156	142	112	30	35.3	11.7	9.8	12.6	0.2	1.0	53	26	10.3	6.8	3.8	43
Apr., May, 1909...	317	125	98	96	2	34.7	9.2	7.1	17.1	0.1	1.2	69	43	13.2	9.3	2.1	51
EFFLUENT A.																	
Oct., Nov., Dec., 1907...	146	50	65	62	3	23.6	4.9	2.6	14.6	0.0	1.5	39	34	6.3	5.4	7.9	45
Jan., Feb., Mar., 1908...	146	47	128	106	36	27.9	7.3	2.7	15.4	0.2	2.3	49	37	8.4	6.6	9.2	30
Apr., May, June, 1908...	200	118	200	130	109	34.1	11.8	5.5	10.3	0.7	5.8	57	37	14.2	6.5	8.0	68
July, Aug., Sept., 1908...	94	53	95	57	38	21.3	6.4	4.3	5.0	4.0	6.7	30	32	7.3	5.5	7.4	88
Oct., Nov., Dec., 1908...	105	68	93	58	35	25.4	6.8	3.4	4.0	0.6	6.7	32	23	5.9	3.5	8.5	48
Jan., Feb., Mar., 1909...	120	89	96	72	24	27.4	7.1	4.1	7.7	0.3	8.2	25	16	6.6	4.0	8.7	30
Apr., May, 1909...	203	246	161	114	47	37.2	15.6	8.4	8.8	0.4	4.0	62	32	13.1	6.5	7.7	48
EFFLUENT B.																	
Oct., Nov., Dec., 1907...	138	48	116	57	59	35.2	5.6	4.2	12.2	0.2	3.0	40	33	7.1	5.3	7.8	46
Jan., Feb., Mar., 1908...	125	38	177	137	40	27.6	6.0	3.1	13.9	0.1	4.5	42	32	7.2	5.5	9.4	36
Apr., May, June, 1908...	201	124	175	108	117	35.5	11.0	5.4	13.0	0.6	5.5	63	30	14.6	7.2	7.7	63
July, Aug., Sept., 1908...	113	72	89	58	31	22.4	6.0	4.1	8.1	0.8	3.4	39	32	8.5	6.2	6.0	54
Oct., Nov., Dec., 1908...	123	87	97	66	31	25.1	7.5	2.9	7.3	0.8	6.6	35	25	6.7	3.9	7.3	87
Jan., Feb., Mar., 1909...	155	111	100	66	34	27.0	6.7	4.3	6.7	0.5	8.8	29	15	6.6	3.5	8.2	49
Apr., May, 1909...	276	240	140	62	78	34.6	11.2	6.2	9.4	0.3	7.5	52	28	10.6	5.5	7.1	91

EFFLUENT C.

Oct., Nov., Dec., 1907...	149	53	112	58	54	22.8	5.3	2.2	13.6	0.2	2.5	38	30	7.3	5.6	7.8	28	46
Jan., Feb., Mar., 1908...	139	37	173	132	41	27.6	6.9	2.9	15.0	0.1	2.7	48	37	8.2	6.4	8.8	27	37
Apr., May, June, 1908...	202	190	292	194	98	40.3	13.5	7.0	14.8	0.5	4.5	66	40	15.4	8.0	5.8	46	55
July, Aug., Sept., 1908...	120	77	106	63	43	24.0	7.7	4.3	7.6	1.0	3.4	42	31	3.9	5.9	5.4	58	68
Oct., Nov., Dec., 1908...	144	97	95	68	27	23.9	6.7	3.2	7.8	0.7	5.5	36	26	7.7	4.8	6.8	75	47
Jan., Feb., Mar., 1909...	161	118	102	72	30	28.1	6.8	4.5	8.2	0.5	8.1	29	16	6.9	4.0	7.1	76	40
Apr., May, 1909.....	315	242	101	55	46	62.9	26.2	17.1	13.2	0.1	6.3	52	25	11.5	5.6	5.3	50	50

EFFLUENT D.

Oct., Nov., Dec., 1907,	136	36	57	40	17	27.4	4.8	3.3	14.9	0.5	3.9	44	39	8.0	6.4	8.2	33	42
Jan., Feb., 1908.....																		

NEW FILTER D.

Mar., Apr., May, June, 1908,	171	65	238	189	49	35.7	10.4	6.6	16.6	0.3	1.8	60	43	11.6	7.7	6.4	26	50
July, Aug., Sept., 1908...	133	68	117	71	46	24.1	7.2	5.5	7.3	1.3	2.8	43	33	9.7	7.1	5.0	41	67
Oct., Nov., Dec., 1908...	153	95	130	91	39	27.6	7.3	4.4	10.1	1.1	4.7	39	28	8.6	5.3	6.6	45	47
Jan., Feb., Mar., 1909...	173	107	107	78	29	31.7	9.2	5.5	11.7	0.8	4.5	29	19	7.7	4.9	6.8	29	39
Apr., May, 1909.....	246	167	118	70	48	35.4	9.5	5.0	15.7	0.2	5.0	54	30	11.7	6.7	4.0	37	50

EFFLUENTS A AND B SETTLED.

Oct., Nov., Dec., 1907...	120	37	68	37	31	22.8	3.7	1.9	14.6	0.1	2.5	35	34	5.2	3.6	...	45	..
Jan., Feb., Mar., 1908...	118	29	168	143	25	28.2	6.5	3.1	14.1	0.4	4.1	45	40	6.3	5.3	...	..	..
Apr., May, June, 1908...	109	46	87	71	16	27.3	5.9	3.4	11.9	0.7	5.4	42	35	7.5	5.3	...	..	..
July, Aug., Sept., 1908...	63	33	40	39	11	20.3	4.5	3.6	6.7	0.8	3.7	32	28	5.7	4.9	...	..	..
Oct., Nov., Dec., 1908...	84	59	52	35	17	19.5	3.6	1.9	6.9	0.7	6.4	27	22	4.9	3.7	...	91	..
Jan., Feb., Mar., 1909...	83	55	40	38	11	26.5	4.8	3.4	7.8	0.5	10.0	22	15	4.3	3.4	...	94	..
Apr., May 1909.....	126	104	55	41	14	29.8	5.1	3.0	9.4	0.4	11.0	33	25	6.1	4.4	...	96	..

EFFLUENTS C AND D SETTLED.

Oct., Nov., Dec., 1907...	128	41	...	...	...	22.6	3.7	2.2	13.9	0.2	2.6	37	35	7.3	5.8	...	31	..
Jan., Feb., Mar., 1908...	125	27	114	91	23	28.1	4.8	2.9	15.9	0.3	4.2	47	41	7.4	6.3	...	27	..
Apr., May, June, 1908...	109	39	58	75	23	32.9	8.8	5.2	15.6	0.5	2.8	45	39	8.8	6.8	...	36	..
July, Aug., Sept., 1908...	59	33	54	44	10	21.1	7.0	4.8	7.0	1.2	3.1	36	30	6.2	5.3	...	59	..
Oct., Nov., Dec., 1908...	85	63	40	34	6	20.1	3.9	2.3	7.9	0.7	5.3	28	24	5.0	3.7	...	71	..
Jan., Feb., Mar., 1909...	83	55	40	38	11	26.9	4.8	3.4	7.8	0.5	10.4	22	15	4.3	3.3	...	59	..
Apr., May 1909.....	127	104	55	41	14	30.0	5.1	3.0	9.4	0.4	11.2	37	25	6.1	4.4	...	40	..

TABLE 2.

AVERAGE ANALYSES OF SEWAGE TRICKLING EFFLUENTS AND SEDIMENTATION EFFLUENTS FOR THE ELEVEN MONTHS, JULY, 1908—MAY, 1909.

Parts per Million.

	SUSPENDED SOLIDS			NITROGEN AS						OXYGEN CONSUMED				DISSOLVED OXYGEN	RELATIVE STABILITY
	Total	Vol.	Fixed	Total	Organic		NH ₃	N O ₂	N O ₃	30' Boiling		15' Cold			
					Tot.	Sol.				Tot.	Sol.	Tot.	Sol.		
Sewage.....	133	101	32	31.7	9.8	6.6	14.7	0.1	0.6	57	38	11.8	8.0	2.2	....
Eff. A.....	111	75	36	27.8	9.0	5.0	6.8	0.5	5.7	39	25	8.2	4.9	8.1	86
Eff. B.....	106	63	43	27.3	7.8	4.4	7.9	0.6	6.6	39	25	8.1	4.8	7.4	88
Eff. C.....	101	64	37	34.7	11.8	7.3	9.2	0.6	5.8	40	24	7.5	5.1	6.1	68
Eff. D.....	118	77	41	29.7	8.3	5.1	11.2	0.8	4.2	41	27	9.4	6.0	5.6	38
A-B settled.....	49	38	11	23.8	4.5	3.2	7.7	0.6	7.8	28	22	5.2	4.1	....	94
C-D settled.....	49	39	10	25.0	5.2	3.6	8.0	0.7	7.5	30	23	5.4	4.2	....	97

points about the chemical figures. The free ammonia values for effluents are distinctly affected by the size of material and depth of filter. The reductions in this constituent were 54 per cent, 46 per cent, 37 per cent, and 24 per cent respectively for A, B, C, and D. The other noticeable difference lies in the soluble oxygen consumed as determined in the cold. Instead of a purification of 40 per cent as shown by Filters A and B, and 36 per cent for Filter C, Filter D only decreased this constituent by 25 per cent. The oxygenation of Effluents C and D was distinctly less than for A and B.

The main difference between the effluents is, however, brought out only by a comparison of the figures for stability. The quarterly averages for this determination are brought together for comparison in Table 3 and are plotted in Figure 1. The data were obtained by daily tests by the methylene blue method and the relative stability number is derived from a scale in which a stability of 21 corresponds to decolorization in 1 day, 37 to decolorization in 2 days, 50 to decolorization in 3 days, 60 to decolorization in 4 days, 68 to decolorization in 5 days, 75 to decolorization in 6 days, 80 to decolorization in 7 days, 90 to decolorization in 10 days, and 96 to decolorization in 14 days, all at 70° F. (Phelps, 1909). Any value over 75 may be considered reasonably satisfactory.

During the first six months of operation in the autumn and winter of 1907-8 the bacteria did not begin active work in the filters and all the effluents were putrescible, losing their oxygen in less than 2 days.

In the spring of 1908, A and B, the 8-foot stone filters, began to improve, and for the last year of operation neither of them showed a quarterly average below 80. In other words these effluents stored

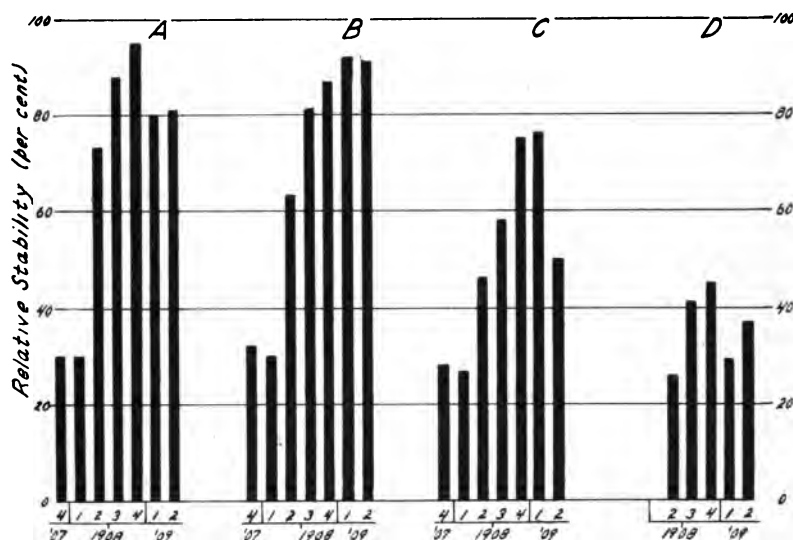


FIG. 1.—Relative stability, quarterly averages, filters A, B, C, and D.

in closely stoppered bottles contained oxygen enough to last for over a week, a condition which could scarcely cause a nuisance in a natural water course under any conceivable circumstances. There was little choice between these two effluents during this period, A being a little more stable in 1908 and B a little better in 1909.

TABLE 3.
RELATIVE STABILITY OF TRICKLING AND SEDIMENTATION EFFLUENTS.
Quarterly Averages.

	1907		1908			1909	
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Effluent A.....	30	30	68	88	95	80	81
Effluent B.....	32	30	63	81	87	92	91
Effluent C.....	28	27	46	58	75	76	50
Effluent D.....	..	29	25	41	45	29	37
A-B settled.....	45	..	..	..	91	94	96
C-D settled.....	31	27	36	59	71	59	40

Filter C, on the other hand, with only 5 feet of depth, gave distinctly inferior results. In every quarter its effluent was less stable

than those of the 8-foot beds. During the autumn and winter of 1908-9 it yielded an effluent of barely passable quality (75), but with the discharge of suspended solids in the spring, the stability fell again to 50. It seems clear that a bed of this character cannot be relied upon to yield a satisfactory effluent.

The open brick bed was unable to produce a stable effluent under the conditions of the experiment. Its stability figure varied between 30 and 45 when it was at its best, decolorizing in 2-3 days. It is somewhat remarkable perhaps that such a crude mechanism should have operated even as well as it did. The attainment of an effluent stable for 2 days even is a notable achievement for a process in which sewage runs rather rapidly over a structure of open brickwork with no filtering action whatever.

3. *Conclusions in regard to depth of beds and size of filtering materials.*—The first general conclusion to be drawn from these experiments concerns the size of the filtering material. The use of fine filling has been urged by many engineers in England. In testifying before the Royal Commission, Garfield, Ducat, and Corbett all fixed the size of stone for trickling beds at values less than one inch (Martin, 1905), and both Barwise (1904) and Raikes (1908) express similar opinions. This sort of material, however, requires very careful preliminary treatment. In America the comparative weakness of the sewage makes such fine material unnecessary and it is possible to use coarse beds and allow more suspended matter to pass upon them. Both at Reading and Columbus the filling material is over $1\frac{1}{4}$ inches in diameter.

The brief experience with Filter D when it was filled with $\frac{1}{2}$ -inch stone showed that the treatment of crude Boston sewage on a bed of this kind was quite out of the question on account of the resultant clogging. A comparison of Filters A and B made it apparent that, with the particular sewage we were working with, $1\frac{1}{2}$ inches was the lower limit for practical efficiency. Filter A was of 1 to $1\frac{1}{2}$ -inch, Filter B was of $1\frac{1}{2}$ to 2-inch stone. The analytical data, as indicated in Table 2, were practically identical for the two beds. In fact Filter B was a little the better in all respects, except as regards free ammonia and dissolved oxygen. Filter A however gave considerable trouble from clogging, while Filter B kept in good condition

with only a reasonable amount of care. $1\frac{1}{2}$ to 2-inch stone may therefore be considered the most suitable material for the purification of sewage like that of Boston.

Granting this premise a comparison of Filters B and C makes it possible to draw a fairly definite conclusion in regard to the relation between depth and efficiency in purification. Filter B had about 7 feet of effective filtering material over the underdrains, Filter C about 4 feet. Filter C had the advantage of somewhat better distribution from a siphon tank. Reference to Table 2 shows that in regard to suspended solids and oxygen consumed there was little or no choice between the beds. Organic nitrogen, particularly in the soluble form, was very much higher in Effluent C. Free ammonia was slightly higher and dissolved oxygen slightly lower. The main difference, however, was in the stability. The great delicacy of the methylene blue reaction is well shown here. Analytical differences between the two effluents are too slight to permit a very sharp distinction between them. Yet the methylene blue test shows that Effluent B had an average stability of over 80 for the last year of operation, and Effluent C rose to 75 only in the cold autumn and winter months, was under 60 in the summer, and fell to 50 in the spring of 1909. Thus the average reducing time for Effluent B was always over a week, while that for Effluent C fell for the spring quarter to 3 days, a decidedly unsatisfactory result.

It may be concluded then that beds of broken stone treating sewage like that with which we worked must be in the neighborhood of 7 feet deep (exclusive of underdrains) in order to insure an effluent having 80 per cent relative stability, a reasonable requirement under local conditions.

4. *The cycle of suspended solids.*—It was noted in our earlier work (Winslow and Phelps, 1907), as it has been observed at Birmingham, England (Watson, 1910), and elsewhere, that the suspended solids in trickling filter effluents exhibit a very marked and characteristic seasonal cycle. The results of the 1905-7 studies and of the present experiments are plotted together for comparison in Fig. 2. In each of the four years represented on the plot there is indicated a great increase in suspended solids during the spring

quarter, the total suspended solids being doubled or tripled in amount. The trickling bed accumulates suspended matter during nine months of the year and discharges its accumulation in the other three. The process begins with the first onset of warmer weather in March or April and culminates in May. The cycle appears to be as constant and regular as any other seasonal biological phenomenon, and it must be reckoned with practically in connection with the effect of a trickling effluent upon the body of water into which it is discharged.

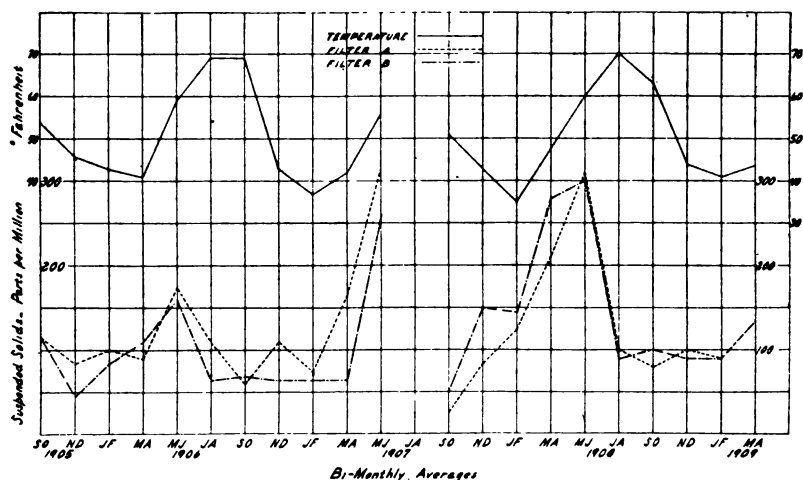


FIG. 2.—Relation between temperature and suspended solids in trickling filter effluents, Sewage Experiment Station of the Massachusetts Institute of Technology.

It must be noted, however, in connection with the character of this spring discharge that the increase in fixed solids is much greater than in the volatile constituents (see Table 1).

5. *Sedimentation of trickling effluents.*—In spite of the stability of the trickling effluents, the presence of more than 100 parts of suspended solids would be likely to cause obnoxious sludge deposits if the effluent were discharged into water where there was not a rather vigorous current. The effluents were therefore submitted to secondary sedimentation for a period of about two hours in the conical tanks described above.

The character of the resulting effluents is indicated in Table 2. Total suspended solids were reduced by 55 per cent, volatile suspended solids by 45 per cent, and fixed suspended solids by 72 per cent (comparing the average of Effluents A and B with the mixed settled effluent). A rather notable feature of the analyses is the marked reduction in soluble organic nitrogen, the appreciable reduction in soluble oxygen consumed, and the definite increase in nitrates. It is clear that during the brief storage period in the tanks the aerobic changes initiated in the filter were continued, leading to further organic purification, aside from the physical effect of sedimentation. This is an interesting indication of the excellent character of the trickling effluents themselves. The sedimented effluents were of course rendered more stable than before treatment, the figure for A and B rising from an average of 87 to 94 and for C and D from an average of 51 to 57.

The amount and character of the sludge removed from the secondary sedimentation tanks is indicated below in Table 4, for all seven quarters in the case of Effluents A and B and for the last three quarters in the case of Effluents C and D.

The volume of sludge produced varied from 3 to 12 cubic yards per million gallons of sewage treated, excluding the first two quarters, in which the discharge of suspended matter was of course comparatively small. The high figures, 6 to 12 cubic yards, occurred in the spring quarters, resulting from the annual discharge of suspended solids at that season.

The disposal of the sludge from this process remains of course a serious problem, as indeed is the case in all methods of sewage disposal. Experiments have been conducted at the station looking toward the disposal of this sludge along two principal lines. In one investigation the sludge was treated in a sort of intensive septic tank in the hope that liquefaction might reduce the amount to be handled. In another investigation the sludge was pressed and a study was made in regard to its possible fertilizing value. Neither line of work yielded encouraging results, and it appears probable that dumping at sea, digging into the land, or pressing and burning remain the most satisfactory methods of sludge disposal.

II. THE PURIFICATION OF SEWAGE BY INTERMITTENT FILTRATION AT HIGH RATES, AFTER PRELIMINARY REMOVAL OF SUSPENDED SOLIDS IN A BIOLYTIC TANK.

(WITH NOTES ON SOME EXPERIMENTS BY J. H. WHITE.)

In Massachusetts, the home of the intermittent sand filter, it has been the general practice to purify sewage at comparatively low rates. The original studies at the Lawrence Experiment Station pointed to a rate of about 100,000 gallons per day as a probable maximum, and in actual operation few of the plants in the eastern states have ever reached this figure. The data recorded by the Massachusetts State Board of Health six years ago (Mass., 1904) were as follows: Stockbridge, 20,000 gallons per acre per day; Andover, Clinton, and Framingham, between 30,000 and 40,000; Brockton, Southbridge, and Spencer, between 40,000 and 50,000; Natick, 50,000; Hopedale and Pittsfield, between 60,000 and 70,000; Westboro, 70,000; Leicester, 80,000; Concord and Marlboro, between 90,000 and 100,000; Gardner and Worcester, between 120,000 and 130,000.

It is apparent however that no such limit as this is necessarily set by the essential nature of the process, so far at least as nitrification goes. A dose of 100,000 gallons an acre corresponds to a depth of less than four inches of sewage. With a clean bed of fairly coarse sand, well leveled and equipped with good distributors, such a dose disappears in half an hour and may be repeated once every six hours without interfering at all with nitrification. A few hours is ample for the bacterial processes of purification, as indicated by numerous laboratory experiments like those of Scott-Moncrieff (1899) at Ashted and of Calmette and his associates at Lille (Rolants and Gallemand, 1901). The difficulty in the practical operation of intermittent filters at high rates arises from the clogging of the surface layers with suspended solids. The period for which the sewage remains on the surface of the beds is gradually prolonged as the clogging increases, until finally a new dose can be applied only after a long interval. In summer this condition can be avoided without any serious difficulty. If sewage is applied at a rate of 400,000 gallons instead of 100,000, sludge deposits on the surface accumulate four times as fast, while for

TABLE 4.
SLUDGE DATA.

AVERAGE OF MONTHS	TOTAL VOL. OF SLUDGE IN GALS.	SP. GRAVITY	GRAMS PER 100 C.C.						TOTAL VOLUME OF SEWAGE IN GALS.			SLUDGE PER MILLION GALS. OF SEWAGE IN Cu. Yds.			POUNDS PER MILLION GALLONS OF SEWAGE							
			Suspended Solids			Organic Nitrogen			Organic Car- bon by Per- manganate			Total	Vol.	Fixed	Suspended Solids		Organic Nitrogen		Organic Car- bon by Permanganate			
			Total	Vol.	Fixed	Total	Susp.	Total	Susp.	Total	Susp.				Total	Susp.	Total	Susp.	Total	Susp.	Total	Susp.
SLUDGE FROM COMBINED EFFLUENTS OF FILTERS A AND B.																						
Oct., Nov., Dec., 1907	60	1.02	8.44	4.78	3.66	...	0.165	...	0.357	240,000	1.20	188	111	77	...	...	...	...	...	5.6		
Jan., Feb., Mar., 1908	102	1.03	9.04	5.38	3.66	...	0.181	...	0.391	252,000	2.59	275	169	106	...	...	...	...	...	13.1		
April, May, June, 1908	406	1.03	9.30	2.11	7.19	...	0.213	...	0.450	290,000	6.37	1,275	497	778	...	...	...	...	...	48.1		
July, Aug., Sept., 1908	176	1.03	8.22	3.54	4.63	...	0.31	...	0.51	221,000	3.90	522	223	299	...	...	...	...	...	29.8		
Oct., Nov., Dec., 1908	246	1.04	8.55	4.36	4.19	0.41	0.40	0.55	0.54	220,000	3.78	545	277	268	25.3	25.0	36.2	36.2	36.2	70.8		
Jan., Feb., Mar., 1909	401	1.05	6.57	3.78	2.89	0.31	0.30	0.42	0.40	386,000	5.27	490	274	216	26.8	26.1	43.1	43.1	43.1	30.0		
Apr., May, 1909	440	1.05	...	...	...	0.29	0.29	0.67	0.67	172,000	12.64	...	...	...	...	36.3	36.3	84.0	84.0	84.0		
SLUDGE FROM COMBINED EFFLUENTS OF FILTERS C AND D.																						
Oct., Nov., Dec., 1908	210	1.04	7.6	4.2	3.3	0.27	0.26	0.50	0.49	266,000	3.98	496	281	214	18.7	17.8	32.4	32.4	32.4	31.9		
Jan., Feb., Mar., 1909	176	1.04	6.1	3.2	2.9	0.30	0.29	0.38	0.37	300,000	3.07	260	138	122	13.7	13.4	19.2	19.2	19.2	18.0		
April, May, 1909	199	1.04	...	...	...	0.49	0.49	0.54	0.53	163,000	6.35	...	...	...	...	24.0	24.0	26.4	26.4	26.0		

successful operation at the high rate the beds cannot be allowed to clog to the extent which would be quite permissible with daily dosing. It is simply necessary, however, to remove the sludge deposit more frequently from a smaller area; and it is probably quite as economical to scrape a ton of sludge from one acre as from two. It is in winter however that difficulty arises. The surface of the beds cannot be reached during the coldest weather, the beds clog, more area is required, and the whole plant must be designed for this condition of excessive strain. When crude sewage is applied to poorly leveled beds, being allowed to flow on as it will without dosing tanks to secure efficient distribution, there seems no hope of securing better results.

In the middle western states, however, intermittent filters have been constructed which appear to be of a more intensive and efficient type. Individual beds are small and carefully leveled; sewage is applied from dosing tanks automatically discharged at frequent and regular intervals; and the sewage is prepared for treatment by the preliminary removal of a considerable proportion of its suspended solids. If we are correct in our conclusion that the clogging of beds in winter is the factor which limits the efficiency of the intermittent filter, preliminary treatment would seem clearly indicated as a rational remedy. At several of the middle western plants rates of 400,000 gallons per acre per day are claimed under this system of operation. Notable examples of such filters are to be seen for instance in the town of Wauwatosa, Wis. The town plant (100,000 gallons) and the County Institutions plant (400,000 gallons) both include septic tanks for preliminary removal of suspended solids, both are dosed several times in the twenty-four hours from automatic dosing tanks, and both operate at a rate of 400,000 gallons per acre per day. The County plant when seen by one of the writers five years ago (Winslow, 1905) was in excellent condition and was yielding an effluent of good appearance. Unfortunately no analyses are obtainable from either of these plants. The septic tank and intermittent filter combination installed by Mr. F. A. Barbour (1905) at Saratoga, N.Y., is designed on the same general plan but is operated at a rate of only 60,000 gallons per acre per

day. Mr. Barbour believes, however, that this rate could be greatly increased if the amount of sewage demanded it.

In some of our earlier experiments (Winslow and Phelps, 1906), we made a study of the operation of sand filters at high rates, with unexpected success. The experimental filters were cypress tanks, 6 feet by 4 feet, filled with 2 feet of sand over 6 inches of gravel underdrainage. The sand had an effective size of 0.17 mm. and a uniformity coefficient of 3.5. The filters were in a covered shed and were thus protected from the severity of the weather, the quarterly average temperature never falling below 39° F. Crude sewage was applied to Filter 1, and septic effluent to Filters 24 and 25. Filter 1 was started in June, 1903, at a rate of 100,000 gallons per acre per day, but the rate was doubled in December and doubled again in June, 1904, being then maintained at 400,000 gallons till the close of the experiments in May, 1905. Filters 24 and 25 were put in operation in March, 1904, and operated consistently at 400,000 gallons per acre per day. The analytical results from all three filters were excellent, as indicated in Table 5. The care of the surface was not serious. Filter 1 was scraped three times and raked once, Filter 24 was raked twice, and Filter 25 was raked once and scraped once.

TABLE 5.
RESULTS OF INTERMITTENT FILTRATION AT HIGH RATES. INDOOR FILTERS. 1904-5.
Parts per Million.

	Filter 1	Filter 24	Filter 25
Nitrogen as Alb. NH_3	0.6	0.6	0.7
Nitrogen as Free NH_3	5.4	4.0	4.9
Nitrogen as Nitrites.....	0.3	0.3	0.2
Nitrogen as Nitrates.....	23.9	21.3	18.8
Oxygen consumed.....	6.8	6.5	6.4
Oxygen dissolved.....	6.3	7.4	7.5

When the new experimental plant for the Sanitary Research Laboratory was built at Old Harbor Point (Winslow and Phelps, 1910), we were anxious to make a test of the possibility of treating sewage on sand filters at high rates on a more practical scale. We therefore constructed an outdoor sand bed of about 500 square feet in area to be operated under normal weather conditions. A general view of the bed is shown in Fig. 3.

The sand bed is 21×22 feet in plan and was built on the old brick floor of a ruined building, once a portion of the garbage reduction plant, the walls and foundation of which were utilized in the construction of the filters. For underdrains, 4-inch half-round tile pipes were laid in four channels in the brick floor. The filtering layer is 3.5 feet deep of beach sand, from the immediate vicinity, with an effective size of 0.36 mm. and a uniformity coefficient of 1.9.

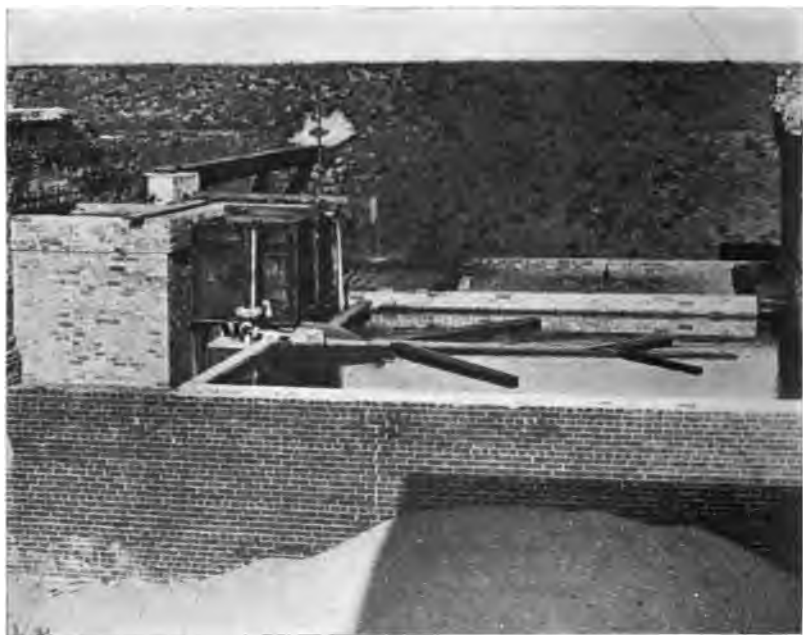


FIG. 3.—View of sand filter bed, Sewage Experiment Station of the Massachusetts Institute of Technology, 1909.

The sewage is distributed on the bed from a dosing tank holding 850 gallons, which at the theoretical rate would discharge about once in 5 hours, giving a rate of 4,250 gallons, or approximately 400,000 gallons per acre per day. The sewage is distributed on the bed by a system of wooden troughs, shown in Fig. 3, with 1-inch outlets, spaced 6 inches apart. The effluent from the sand filter passes from the underdrains to cement channels in an arched brick tunnel under the floor, which serves as a sampling chamber.

The tank used for the preliminary treatment of the sewage to

be applied to the sand filter is of a somewhat peculiar type, and to distinguish it from the ordinary septic tank we have called it a biolytic tank.

The actual removal of suspended solids is of course accomplished in almost all preliminary processes by the simple physical action of sedimentation. The proportion of suspended solids thus removed is usually between 50 and 65 per cent with American sewages (Fuller, 1909), although in England and Germany considerably higher results have been reported. The septic tank was originally designed not to improve the removal of suspended solids but to eliminate by liquefaction a portion of the material deposited. The early claims to the effect that 75 to 80 per cent of the deposited sludge could be thus liquefied have not, however, been generally substantiated. Most of the septic tanks which have been carefully studied, both in England and in the United States, have liquefied between 25 and 40 per cent of the suspended solids which they removed. At certain plants, as at Birmingham, England, values as low as 10 per cent have been recorded.

In considering the limitations of the septic process which cause it to stop so far short of complete decomposition it seemed probable that the accumulation of waste products from the process itself might be one of the principal factors in checking its progress. This is a common phenomenon in all bacteriological reactions, the removal of the end-products being almost invariably a necessary condition for continued activity. An experiment made some years ago at the Lawrence Experiment Station is suggestive of such an action, since it indicates that a shorter storage period tends to facilitate liquefaction and a shorter storage period means less accumulation of waste products. A small septic tank was dosed, not with sewage, but with the more concentrated sludge from settled sewage. For six months the storage period was from five to fifteen days, and sludge accumulated, filling up 60 per cent of the tank. The rate was then increased, so that the storage period was reduced to 49 hours, when the accumulated sludge decreased to 8 per cent and did not further increase for a year (Massachusetts, 1901). At Leeds it was found that a 72-hour septic period interfered with the solution of sludge (Leeds, 1905).

In some of our own earlier experiments Winslow and Phelps, 1906, we found that sludge liquefaction was much more active with a 12-hour period than with a 24-hour period and more active with a 24-hour period than with one of 48 hours.

In the spring of 1909, at the suggestion of one of the writers, Mr. J. H. White made a laboratory study of this problem which tended to confirm these conclusions. Mr. White took two 3-liter bottles, A and B. Into A was poured 1,000 c.c. of sewage sludge and 1,000 c.c. of tap water, into B 1,000 c.c. of sludge alone. Bottle A was fitted with an inlet tube by which fresh tap water could be admitted through a stopcock, an outlet tube discharging by a siphon into a second stoppered bottle, a gas outlet through which the accumulated gas could be discharged, and a mercury gage to measure gas pressure. Bottle B was fitted with a gas outlet and pressure gage alone. Both were tightly sealed with sealing-wax and paraffin.

Daily observations were made of the temperature and pressure in each bottle and the gas was then allowed to escape. Each day 200 c.c. of fresh tap water was added to Bottle A and 200 c.c. of the contained liquid siphoned off. The sludge was analyzed at the beginning of the experiment and the contents of both bottles at the close; and weekly analyses were made of the effluent from Bottle A. Vigorous septic action took place in both cases, as manifested by the formation of scum and the production of gas bubbles. The fermentation in both bottles continued to the end of the experiment (33 days).

Mr. White calculated from his analyses the actual amount of various constituents in the original sludge, in the contents of Bottle A at the end plus the effluents from Bottle A, and in Bottle B at the end. The results, as shown in Table 6, indicate very clearly that the liquefying processes were markedly favored by the flushing out with fresh tap water. Bottle A yielded more than twice as much organic nitrogen in solution, free ammonia, and fixed solids in solution and nearly twice as much volatile solids in solution, as compared with Bottle B. It left, on the other hand, only 8.66 gms. of volatile solids in suspension against 14.20. Fixed solids in suspension were increased in the A effluent.

If our conclusions are justified and the limitations of the liquefying activity of the ordinary septic tank are due to the accumula-

tion of toxic waste products, the Hampton hydrolytic tank and the Imhoff deep tanks used in West Germany are designed on a principle that is not favorable to sludge liquefaction. In both these tanks the sludge is separated from the flowing sewage and stored in a liquefying chamber where it is subjected to intensive septic action with a minimum of opportunity for the removal of end-products. We have attempted to secure precisely the opposite result by using the deep conical tank with an inflow at the bottom and an outflow at the top, the sludge being constantly washed in a

TABLE 6.
RESULTS OF SEPTIC TREATMENT WITH AND WITHOUT FLUSHING.
(Experiments made by J. H. White.)

	Sludge before Treatment	Contents of Bottle A + Effluent	Contents of Bottle B
Nitrogen (parts per million):			
Total organic	1,300	1,504	1,200
Organic in solution	120	56	188
Free Ammonia	49	386	144
Solid (gms.):			
Total	35.20	34.64	31.20
Total in solution	6.00	13.74	7.40
In suspension	29.20	20.90	23.80
Volatile:			
Total	17.90	14.08	17.60
In solution	2.12	5.42	3.40
In suspension	15.78	8.66	14.20
Fixed:			
Total	17.30	20.56	13.60
In solution	3.88	8.32	4.00
In suspension	13.42	12.24	9.60

current of fresh sewage so that the products of decomposition may be removed. The tank is essentially like the Dortmund tank used for many years for sedimentation of sewage. Tanks of this general pattern are in operation with great success at Birmingham, England (Watson, 1910). So far as we are aware, however, all such tanks have hitherto been used for plain sedimentation, the sludge being removed too frequently to permit of septic action. In the case of our tank no sludge has been removed for a year and septic processes were obviously active. On the other hand, as the essential principle of the septic tank is recognized to be the retention of the sewage so as to promote anaerobic conditions as far as possible, while our aim is to limit these conditions, this tank is hardly a septic tank in the ordinary use of the term and might better be called a biolytic tank.

The tank itself is square at the top, and 7 feet across (see Fig. 4). The vertical sides extend downward for 2.5 ft., below which the walls converge to form a hopper. They have a slope of about 55 degrees with the horizontal. The capacity is 1,540 gals., and the flow period 8.5 hrs. The sewage enters through a 2-inch pipe about 9 inches from the bottom and the effluent is skimmed off at the surface by four 60-degree triangular metal weirs, placed at the

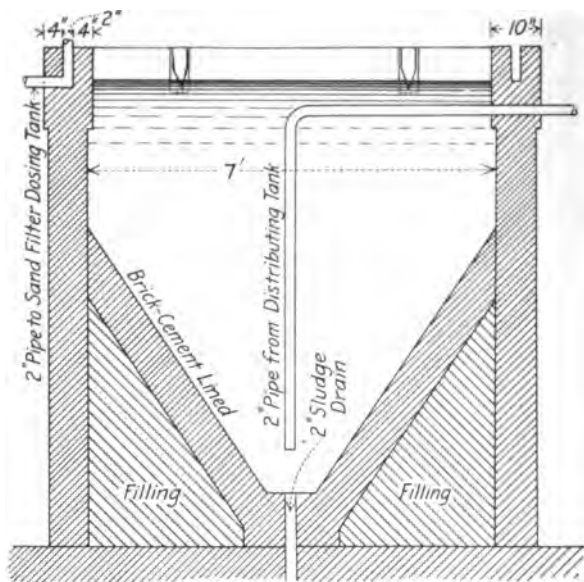


FIG. 4.—Cross-sectional view of biolytic tanks, Sewage Experiment Station of the Massachusetts Institute of Technology.

corners and discharging into 2-inch channels in the walls. Scum-boards protect these weirs. At the bottom of the tank is a 2-inch effluent drain for sludge.

The biolytic tank was first put in operation in July, 1909, and has since been in continual use, for six days in the week, and for seven days during the colder months. Samples are collected from all parts of the experimental plant every three hours, and the samples are mixed, chloroformed, and analyzed once a week. The analytical methods used include determinations of turbidity and

sediment, suspended matter, nitrogen as free ammonia, nitrites, nitrates and total Kjeldahl, oxygen consumed, total and dissolved, by both the 30-minute boiling and the 15-minute room temperature method.

The general character of the crude sewage is indicated by the monthly averages in Table 7. It represents the mixed sewage from the entire South Metropolitan District of Boston (about 90 million gallons a day), after screening through coarse bar screens at the city pumping plant and the removal of heavy grit in a small detritus chamber at our own station. The sewage of Boston is rather weak for the sewage of a large American city, particularly as regards suspended solids and free ammonia.

TABLE 7.
COMPOSITION OF CRUDE SEWAGE.
Monthly Average of Weekly Composite Samples.

MONTH 1909-10	TURBIDITY	SEDIMENT	SUSPENDED SOLIDS			NITROGEN AS						OXYGEN CONSUMED			
			Total	Vol.	Fixed	Total	Organic		Free NH ₃	N ₂ O ₃	N ₂ O ₅	30' Boiling		15' Cold	
							Total	Sol.				Total	Sol.	Total	Sol.
August.....	305	150	156	130	26	29.5	13.1	6.7	16.2	.1	.1	73	53	19.3	12.0
September.....	420	280	212	145	67	30.0	14.8	9.3	14.8	.0	.0	68	39	17.4	8.9
October.....	335	220	139	109	30	24.0	9.0	3.8	14.9	.2	.1	70	49	15.8	12.9
November.....	340	220	184	139	45	27.0	9.5	6.1	17.5	.1	.3	76	47	17.1	9.6
December.....	315	190	112	74	38	27.0	14.0	7.3	12.1	.1	.3	56	40	14.2	8.1
January.....	290	160	114	76	38	18.0	7.7	5.3	8.7	.1	1.2	65	46	12.0	7.1
February.....	405	190	180	100	80	21.0	13.4	10.9	6.6	.1	.8	74	58	13.7	9.2
March.....	240	160	200	.....	.....	23.0	11.3	7.8	10.0	.1	1.2	59	35	12.9	8.9
April.....	340	230	150	100	50	30.0	15.5	13.3	13.3	.1	1.2	74	49	18.1	12.4
May.....	370	205	180	120	60	24.0	9.2	7.0	18.0	.1	.2	85	72	20.0	12.9
Average.....	365	200	163	110	48	25.3	11.7	7.7	13.2	.1	.5	70	49	16.0	10.2

Marked seasonal variations are apparent in free ammonia and in oxygen consumed as determined in the cold, both values falling during the winter months and rising as increasing temperatures facilitate bacterial action. Suspended solids are low during the freezing weather of December and January and rise again with the spring thaws.

The work of the biolytic tank in regard to the removal of sus-

pended solids may be estimated by comparing the analyses of its effluent for the corresponding period as they are given in Table 8.

TABLE 8.

COMPOSITION OF EFFLUENT FROM THE BIOLYTIC TANK. MONTHLY AVERAGES OF WEEKLY COMPOSITE SAMPLES.

Parts per Million.

MONTH 1909-10	TURBIDITY	SEDIMENT	SUSPENDED SOLIDS			NITROGEN AS						OXYGEN CONSUMED			
			Total	Vol.	Fixed	Total	Organic		Free NH ₃	N O ₂	N O ₃	30' Boiling		15' Cold	
							Total	Sol.				Total	Sol.	Total	Sol.
August.....	165	55	77	60	8	24	6.7	3.6	17.2	.0	.1	53	39	18.0	15.7
September.....	230	120	123	92	31	27	11.1	6.4	16.1	.0	.0	56	35	17.0	11.3
October.....	200	110	88	74	14	21	5.3	4.5	15.5	.0	.0	57	37	15.5	12.2
November.....	195	105	59	49	10	23	6.1	5.0	16.4	.0	.0	55	40	15.0	12.3
December.....	185	75	70	45	25	23	8.9	4.4	14.3	.0	.0	53	39	14.1	10.6
January.....	210	100	70	40	30	18	7.2	5.0	9.5	.2	.7	49	35	11.5	8.2
February.....	260	120	90	60	30	19	8.6	4.1	9.9	.1	.4	49	37	11.4	7.7
March.....	240	125	90	..	..	21	8.6	6.4	12.1	.1	.1	47	28	14.1	11.0
April.....	180	100	70	50	20	25	6.0	5.8	18.5	.0	.0	60	40	20.8	17.5
May.....	175	75	70	50	20	23	6.4	6.0	16.6	.0	.0	65	44	24.4	21.9
Average.....	204	98	81	58	21	22	7.5	5.1	14.6	.0	.1	54	37	16.2	12.8

Comparison of the final averages in Tables 7 and 8 shows the usual changes, characteristic of septic action. Free ammonia was increased from 13.2 parts to 14.6 parts; and of the unstable carbonaceous compounds determined by oxygen consumed in the cold the soluble portion was increased from 10.2 parts to 12.8 parts. Of the organic nitrogen, the suspended portion was reduced from 4.0 parts to 2.4 parts (40 per cent), and the dissolved portion from 7.7 parts to 5.1 parts (34 per cent). The oxygen consumed determined at 212° F. showed similar decrease from 21 to 17 (19 per cent) for the suspended portion and from 49 to 37 (24 per cent) for the dissolved portion.

The principal changes, however, were of course in the suspended matter. The sediment was reduced from 200 to 98 (51 per cent); the total solids from 163 to 81 (50 per cent); the volatile portion from 110 to 58 (47 per cent); and the fixed portion from 48 to 21 (56 per cent). These results correspond pretty well with those obtained from good septic tanks in actual practice, as indicated in Table 9, compiled from the final report of the British Royal Commission (1908) and from the results of certain American tanks.

TABLE 9.
REDUCTION OF SUSPENDED SOLIDS BY SEPTIC TREATMENT.

Plant	Per cent Reduction	Plant	Per cent Reduction
Andover, England.....	30	Hartley Wintney, England...	54
Slaithwaite, England.....	34	Knowle, England.....	57
Worcester, Mass.....	35	Saratoga, N.Y.....	65
Prestolee, England.....	42	Exeter, England.....	67
Caterham, England.....	47	Reading, Pa.....	74
Columbus, Ohio.....	49	York, England.....	75
Accrington, England.....	50	Rochdale, England.....	86
Boston, Mass.....	50		

The variations at different plants are of course very great, since both the nature of the sewage and the construction of the tanks influence the end result. Seven of the other fourteen plants recorded, however, show a purification less than that effected by our tank, while the other seven yielded better results. This seems a good showing in view of the fact that the weakest point in a deep continuous-flow tank lies in its tendency to discharge too much of the suspended matter it receives.

In regard to the other requisite in a successful tank, the liquefaction of the deposited solids, the biolytic tank has proved notably successful. After eight months' use, in the third week of April, 30 gallons of sludge were withdrawn for analysis and on June 13, after ten months' operation, the tank was stirred up and emptied and a representative sample taken for analysis. The withdrawal of sludge and the examination of the tank were solely for the purpose of studying the process and were not conditioned by any obvious accumulation of sludge; and the weekly analyses showed no tendency to deterioration. In fact no accumulation of sludge was apparent by probing from the top of the tank.

From the average analyses of sewage and effluent, and from the analyses of sludge and tank contents, we have calculated the removal of suspended solids and organic nitrogen and the proportion of the deposited solids liquefied, in Table 10. The figures cover the whole period up to June 13 and therefore differ slightly from those given in Tables 7 and 8.

These figures show, as do those in Tables 7 and 8, a removal of about half the suspended solids in the crude sewage. The most important point however is brought out in the last line, which shows that 72 per cent of the total solids and 81 per cent of the volatile

TABLE 10.
EFFICIENCY OF BIOLYTIC TANK. AUGUST, 1909—JULY, 1910.
Parts per million.

	SUSPENDED SOLIDS			SUSPENDED ORGANIC NITROGEN
	Total	Volatile	Fixed	
Sewage.....	166	114	52	4.4
Tank effluent.....	77	50	27	2.4
Deposited in tank.....	89	64	25	2.0
Found in tank.....	25.2	12.6	12.6	.9
Per cent of total removed by tank.....	54	56	48	45
Per cent of deposited solids dissolved.....	72	81	49	52

solids deposited were eliminated by septic action. This result is a very favorable one, as indicated by Table 11, in which the figures for a number of English and American tanks are brought together for comparison (from Kinnicutt, Winslow, and Pratt, 1910).

TABLE 11.
LIQUEFYING EFFICIENCY OF SEPTIC TANKS.
Percentage of Deposited Solids Dissolved.

Place	Total Solids	Place	Total Solids	Organic Solids
Birmingham, England...	10	London, England.....	41	71
Exeter, England.....	25	Boston, Mass.†.....	42	81
Manchester, England...	26	Glasgow, Scotland.....	50	..
Ilford, England.....	30	Hampton, England.....	..	58
Sheffield, England.....	30	Saratoga, N.Y.....	69	..
Accrington, England.....	35	Boston, Mass.†.....	72	81
Worcester, Mass.....	39	Exeter, England§.....	80	..
Leeds, England.....	20-60			
Huddersfield, England..	40			

* Royal Commission studies.

† 1905-7. Rectangular tanks.

‡ 1909-10. Hydrolytic tank.

§ Early reports from town.

Except for the very high reduction originally reported from Exeter, the efficiency of the biolytic tank in the liquefaction of total suspended solids appears to be much greater than that of most septic tanks of the ordinary form. The tank at Saratoga is the only one which equals it, and this tank has the advantage of receiving its chief burden in summer when the temperature is favorable to active bacterial development. In regard to volatile suspended solids the old rectangular tanks used at the Technology Station in 1905-7 were equally efficient. These tanks, however, were in a shed and thus protected from winter weather, and their vigorous liquefaction of volatile suspended solids was counterbalanced by an actual increase in fixed suspended solids.

Altogether it seems that the use of a conical tank with upward flow for septic treatment is justified by our results. The removal of suspended solids is about as good as that attained with a rectangular tank and the liquefaction of the deposited solids is distinctly better.

The effluent from the biolytic tank, as noted above, passed to a dosing tank of 850 gallons capacity, which if discharged once in five hours gives a rate on the sand bed of 4,250 gallons per day or approximately 400,000 gallons per acre per day.

The actual net rates on account of slackening in the flow of the septic tank and Sunday rests were considerably lower, as shown by months in Table 12.

TABLE 12.
SAND FILTER RATINGS.
Rates in gallons per acre per day.

1909-10	No. Gallons
Up to January 1.....	293,000
January.....	342,000
February.....	337,000
March.....	315,000
April.....	221,000
May.....	245,000

The general operation of the bed at this high rate was notably successful. The dose of sewage disappeared ordinarily in fifteen minutes. This period gradually increased however in the colder weather until sewage stood on the bed from one dosing to the next. It was merely necessary to rake the bed to relieve the clogging.

During ten months of operation no material was removed from the bed and there was no apparent tendency to clogging or other sign of deterioration. The surface was raked six times, on November 6, January 24, January 31, February 28, March 7, and April 9. On November 22 the bed was furrowed for the winter and on March 17 it was leveled again. Ice formation was complete over the furrows for periods of three or four days in the coldest weather. The warmth of the sewage beneath together with that from the sun soon broke the ice directly above the channels. No doubt the frequent application of sewage tended to protect the bed from the more severe effects of winter weather.

The sand bed will undoubtedly clog in the future and it will be

necessary to scrape its surface and remove sludge deposit as is done in all plants under actual operation. The important point however is that with the application of septicized effluent the clogging is so gradual that the accumulation of solids from ten months of operation did not affect its efficiency in any appreciable degree. Such being the case, the removal of sludge deposit during the cold winter months could easily be avoided, without reducing the intensive rate of operation.

The composition of the filter effluent is indicated by the results tabulated in Table 13.

TABLE 13.
COMPOSITION OF EFFLUENT FROM THE INTERMITTENT FILTER.
Monthly Averages of Weekly Composite Sample. Parts per million.

MONTH 1909-10	NITROGEN AS					OXYGEN CONSUMED		RELATIVE STABILITY
	Total	Organic	Free Ammonia	Nitrites	Nitrates	30' Boiling	15' Cold	
August.....	19	10.5	2.2	.2	6.2	12	2.0	96+
September.....	19	7.4	1.9	.1	9.5	16	1.9	96+
October.....	21	7.1	.4	.3	13.0	14	1.6	93
November.....	26	5.5	5.7	.4	14.0	17	2.4	96+
December.....	28	8.5	4.3	.3	15.3	16	2.5	95
January.....	26	5.2	5.7	.1	15.3	15	1.9	96+
February.....	22	5.1	4.2	.1	12.7	11	2.1	96+
March.....	28	3.3	4.0	.0	21.0	14	1.6	96+
April.....	48	4.0	1.5	.0	42.0	20	2.4	96+
May.....	45	2.3	1.1	.1	41.6	18	3.2	96+
Average.....	28	5.9	3.1	.2	19.1	15	2.2	96

The usual seasonable phenomena are indicated, free ammonia and organic nitrogen rising in November and December as the cold weather checks bacterial action. In March these organic constituents drop again, and the nitrates rise, reaching the enormous value of 40 parts and over in April and May. In these two months about 90 per cent of the total nitrogen discharged was in the nitric form.

A better idea of the work of the bed may be gained from Table 14, in which the effluent is compared with the applied liquor. In spite of the fact that the total nitrogen was 27 per cent more in the effluent than in the applied liquor (due perhaps in part to concentration by evaporation from the surface of the bed), the free ammonia showed a purification of 79 per cent, the oxygen consumed determined at 212° F. a purification of 72 per cent, and the more

unstable portion as determined in the cold a purification of 86 per cent. For the whole period 69 per cent of the nitrogen present in the effluent was in the mineral form.

TABLE 14.
EFFICIENCY OF INTERMITTENT FILTER.
Parts per million.

	NITROGEN AS					OXYGEN CONSUMED	
	Total	Organic	Free Ammonia	Nitrites	Nitrates	30' Boiling	15' Cold
Septic Effluents....	22	7.5	14.6	0.0	0.1	54	16.2
Sand effluents.....	28	5.9	3.1	0.2	19.1	15	2.2
Percentage purification.....	21	...	79	...	....	72	86

The effluent from the bed was always of excellent appearance and free from turbidity and odor. Its stability is given in the table as 96. This corresponds to the maximum period of 14 days for which the methylene blue samples were kept (Phelps, 1909). As a matter of fact the true stability must have been between 96 and 100, probably nearer 100. Out of 41 weekly averages for stability 35 were 96, or the maximum; one week averaged 95, two weeks 94 each, one 93, one 92, and one 88. The last of these values corresponds to a reducing time of between 9 and 10 days, so that it is evident that the effluent was uniformly of a very high quality.

These experiments are being continued and will be more fully reported after a longer period. After ten months of operation, however the results seem to indicate clearly that intermittent sand filters can be operated at high rates (400,000 gallons per acre per day) with marked success, if the beds are carefully constructed of fairly coarse sand and dosed at regular and frequent intervals with sewage from which suspended solids have been partially removed by preliminary treatment. Our experience suggests that preliminary treatment can with advantage be carried out in a deep tank with upward flow, the removal of suspended solids by such a tank being fairly efficient and the liquefaction of the deposited solids unusually high.

REFERENCES.

- BARBOUR, F. A., 1905. "The Sewage Disposal Works at Saratoga, N.Y.," *Journal of the Association of Engineering Societies*, 34, p. 33.
- BARNES, S., 1904. *The Purification of Sewage*, p. 122.
- BRITISH ROYAL COMMISSION ON SEWAGE DISPOSAL, 1908, 4th Report.
- FULLER, G. W., 1909. "The Principles of Sewage Purification," *Engineering Record*, 59, p. 622.
- KINNICUTT, L. P., WINSLOW, C.-E. A., and PRATT, R. W., 1910. *Sewage Disposal*, p. 145.
- LEEDS, 1905. *Report on the Experiments in Sewage Disposal Carried Out at the Knostrop Sewage Works, Leeds, from 1895 to 1905*. By Colonel T. W. Harding and W. H. Harrison.
- MARTIN, A. J., 1905. *The Sewage Problem*, p. 214.
- Massachusetts State Board of Health Report, 1903, p. 446; *ibid.*, 1901, *Annual Report for 1900*, p. 374; *ibid.*, 1904, *Annual Report for 1903*, p. 446.
- PHELPS, E. B., 1909. "The Disinfection of Sewage and Sewage Filter Effluents, with a Chapter on the Putrescibility and Stability of Sewage Effluents," *United States Geological Survey, Water-Supply Paper 226*, Washington. Also, *Contributions from the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology*, 1909, Vol. 5.
- RAIKES, H. P., 1908. *Sewage Disposal Works*, p. 166.
- ROLANTS, E., and GALLEMAND, E.-A., 1901. "La nitrification dans les lits bactériens aérobies," *Revue d'hygiène*, 23, p. 968.
- SCOTT-MONCRIEFF, W. D., 1899. "High Nitrification in Sewage Treatments," *Jour. Sanitary Inst.*, 20, p. 653.
- WATSON, J. D., 1910. (a) "Birmingham Sewage-Disposal Works," *Proc. Inst. Civil Engineers* (in press).
- , 1910. (b) "Birmingham Sewage-Disposal Works," *Proc. Inst. Civil Engineers* (in press).
- WINSLOW, C.-E. A., 1905. "A Winter Visit to Some Sewage Disposal Plants in Ohio, Wisconsin, and Illinois," *Jour. Asso. of Engineering Societies*, 34, p. 335. Also, *Contributions from the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology*, Vol. 3.
- WINSLOW, C.-E. A., and PHELPS, E. B., 1906. "Experiments on the Purification of Boston Sewage, 1903-5," *Contributions from the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology*, 22, p. 126. Second ref., p. 125.
- WINSLOW, C.-E. A., and PHELPS, E. B., 1907. "Investigations on the Purification of Boston Sewage in Septic Tanks and Trickling Filters," *Technology Quarterly*, 20, pp. 387-452. Also, *Contributions from the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology*, 4, 1909.
- WINSLOW, C.-E. A., and PHELPS, E. B., 1910. "The New Sewage Experiment Station of the Massachusetts Institute of Technology," *Engineering News*, 63, p. 652.



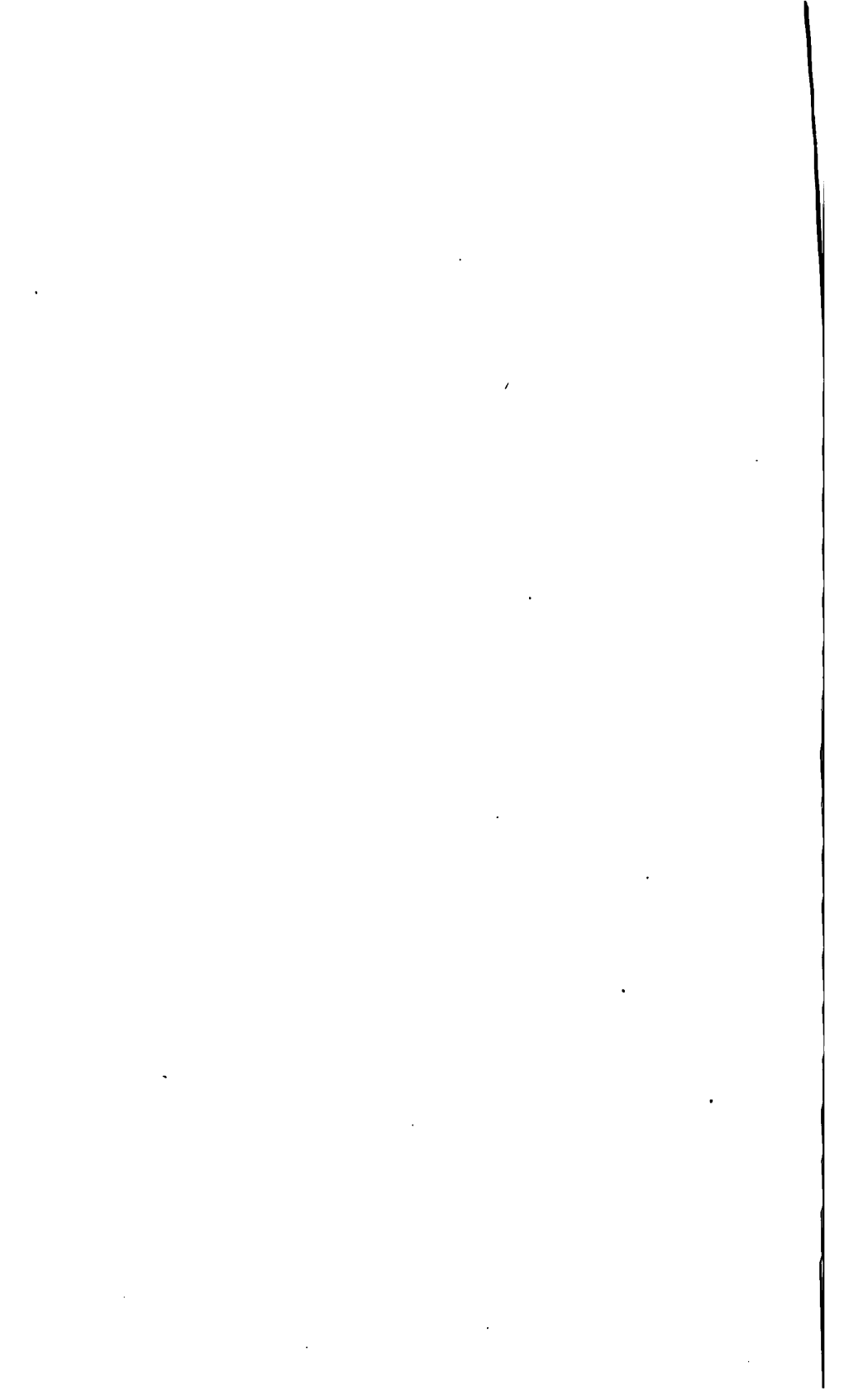
Sewage Purification; its theory and present day practice

BY

EARLE B. PHELPS



Reprinted from the Journal of the Engineers' Society of
Pennsylvania, Volume 2, Number 11, November, 1910
Pages 447-479



SEWAGE PURIFICATION; ITS THEORY AND PRESENT DAY PRACTICE.

BY EARLE B. PHELPS.

Contents.

- I. The Sewage Disposal Problem.
- II. Biological Processes.
 - General.
 - The Process of Decay.
 - Sewage Irrigation.
 - The Slow Sand Filter.
 - The Septic Tank.
 - The Contact Bed and its Modifications.
 - The Trickling or Sprinkling Filter.
- III. Mechanical Processes.
 - Screens and Screening.
 - Detritus Tanks.
 - Plain Sedimentation.
- IV. Chemical Processes.
 - Chemical Precipitation.
 - Chemical Disinfection.
- V. Engineering Features.
 - Classification of Processes.
 - Selection of a Process.
 - The Cost of Sewage Purification.

I. THE SEWAGE DISPOSAL PROBLEM.

The problem of sewage disposal is a problem of modern community life. Sewage disposal on the farm is not a problem. It involves the use of the natural instinct of cleanliness, rather than the scientific intelligence which is now grappling with the larger question. Community life is a life of crowding, in point of time as well as of space, and one of the results of this congestion is the sewage problem. The farm becomes a village and wells are contaminated by nearby privies; the village becomes a city, and wells and privies are alike abandoned for a public water supply and sewers. The former comes from upstream, the latter run down stream, and for a while all is well. Other cities grow along that stream using it alike for water supply and sewerage, and the sewage disposal problem has its birth. Perhaps new water supplies are sought and the pollution of the river continued. Later the taking of shell-fish from areas over which these waters flow is abandoned. Finally, with increasing density of population,

Sewage Purification—PHELPS.

increasing crowding, the once pure stream becomes such an offense to the physical senses and a menace to the health of the people that by universal consent something must be done. This is the mature sewage disposal problem. The scene changes but the plot is the same. All over the civilized world people are in one or another stage of learning that the discharge of untreated sewage into a river will sooner or later, with increasing populations, bring about undesirable conditions. Many have solved their problems. In the Old World in particular a condition of stable equilibrium has been reached in which, by common consent borne of sad experience, it is agreed that rivers shall not be grossly polluted. In this country we have not advanced so far and waters like the Passaic in New Jersey, and the Naugatuck in Connecticut, are some of our early and crude attempts at solving the problem.

There is of course the other side of the question. A river has a certain power to preserve its own purity. If the stream be large and the community small, physical nuisance may not follow. Even the more obscure dangers from the germs of disease, likely to be present at any time in sewage, may be minimized by sufficient dilution and in sufficient time. But the fixing of these critical conditions; the adjustment of all the nice problems of equity whereby it may be determined what right each community has in the stream in question, either to pollute it or to utilize it; the safeguarding of the public health and of the public wealth by the protection and conservation of these waters; and finally the determination of what kind and degree of purification shall be given to the sewage when treatment is necessary; these constitute the sewage disposal problem.

There are two chief forms of argument against the discharge of untreated sewage into streams. These we may designate the sanitary argument and the economic argument. The one relates to the public health, the other to the public wealth.

The discharge of sewage into waters that serve also as sources of water supply is obviously contrary to the teachings of sanitary science. Even though filtration of the water be undertaken there is still an added menace, a potential injury to those using the water. Purification of surface waters is resorted to as a safeguard against accidental pollutions of a serious nature and against minor continuing pollutions which seem unavoidable; but the deliberate, gross and continuing pollution which is involved in the discharge of a city's sewage into another city's water supply damages the latter and is contrary to the laws of equity as well as of sanitation. A water filter, like other works of man, is not infallible. Epidemics of typhoid fever have followed the accidental failure of such filters, when they have been the only safeguard between a polluted river and a city water supply. Waters of this class must, in the very nature of the case, be protected as far as possible against pollution.

Next to water supplies, the shell fish industry, at the present moment, is the most important factor in this problem. Here there is no possible alternative. In the light of our knowledge of the

Sewage Purification—PHELPS.

relation of shell-fish to disease it is self-evident that waters from which shell-fish are taken must be comparatively free from sewage pollution.

In both these cases the question arises how far it is wise to utilize rivers to carry off sewage and waste and, in consequence, to exclude their use for the purpose of domestic water supply, and to prohibit the taking of shell-fish from beds over which they flow.

This brings us to the other aspect of the matter,—the economic aspect. Sanitary questions are in themselves primarily economic but after all sanitary requirements have been satisfied there are still economic arguments for and against stream pollution.

This is best illustrated in the shell-fish situation. It would obviously be unwise to attempt the purification of New York Harbor to such an extent that shell-fish might be taken with safety within the upper bay. It would be equally disastrous to permit such pollution of the Chesapeake and tributary waters as would even threaten to harm the valuable oyster industry of Maryland and Virginia. Between these two extremes lie all varieties of conditions. Whether it be laid down as law that oysters shall not be taken from sewage polluted waters or whether it be established that waters flowing over oyster beds shall not be polluted, is for the economist, not the sanitarian, to decide. The pollution of bathing beaches and many other minor sanitary questions also have their economic aspect.

There is also the broader economic question that appears when stream pollution reaches a more serious stage. In many of our rivers it is not a question of drinking-water or of shell-fish. Malodorous and unsightly conditions exist which destroy major fish life, depreciate property values, and bring a just reproach upon the community. Fortunately such conditions usually bring their own remedy through the force of public opinion. With divided responsibility scattered over many communities there is a tendency to avoid the responsibility by shifting it upon a neighbor, but with good state laws and active state authorities results are being obtained in our more advanced states which are gratifying and satisfactory.

On the other side of the question economic conditions demand that the fullest reasonable use be made of the purifying mechanism of streams and other bodies of water. If without offense and without detriment to any other interest these bodies of water can be made to receive and care for the sewage of a community, unpurified or partially purified, it would be unwise not to take advantage of the opportunity. This is particularly the case with the great seaboard cities. This problem of disposal without treatment or disposal by dilution as it is sometimes called, has probably received less scientific thought and attention than any other single purification process, despite the fact that it is one most widely made use of. For this reason any discussion of the theory and scientific basis of this process is impossible. It is a method of disposal and can be made a scientific method of purification, but before that is possible, our present guesses as to the possible ca-

Sewage Purification—PHELPS.

capacity of a stream to assimilate sewage must be replaced by a real study of the factors involved. Always assuming the sanitary considerations to have been satisfactorily settled, there remain many variable factors. Among these we may note the character of the stream as regards its contour, mean velocity and discharge, relation to maxima and minima to these means, and many other factors on the one hand; and on the other the character of the sewage particularly in the feature which the writer has defined in an earlier paper as the condition factor. Recent experiments have shown that within one month, owing chiefly to a considerable rise in temperature, the sewage of a portion of Greater New York has undergone a five-fold increase in its ability to absorb oxygen from water into which it may be discharged. This change is so subtle as to have escaped notice entirely in the ordinary analytical procedure. In the light of such facts as these, one hesitates to assign any stated number of cubic feet per second of diluting water to the sewage of one thousand persons, without further knowledge of the condition of the sewage.

Therefore the present discussion of the theory and practice of sewage purification methods will be confined to those processes which have received scientific study. Some definite knowledge is available as to the action of these processes and upon this basis is hoped to construct a comprehensive theory of sewage purification methods and their application.

II. BIOLOGICAL PROCESSES.

General.

When the author of the Mosaic law gave specific directions for the burial of all excrement he doubtless but voiced a custom which had evolved with man himself. The earth has ever been the final repository of the wastes of life. It remained, however, for modern bacteriology, in our own day, to explain, even approximately, the mysterious process by which all life and its multitudinous products must eventually return to the "vile dust from whence they sprung." Because these processes bear about the same relation to the living world that the law of gravitation does to the physical world, being equally universal and fundamental, their study is, at least, one of general interest. These studies at once assume a practical aspect when we learn that our modern biological processes of sewage purification are but scientific adaptations of this universal law of biological decay. It is indeed true that septic tanks and the various kinds of so-called filters, are essentially hot-beds or incubation beds in which the processes of nature are hastened, or forced; and that our present day methods of sewage disposal differ in no essential feature from those of Moses. Therefore, any study of the fundamental principles of sewage disposal must of necessity begin with a study of the powers of the soil to destroy organic matter, and with the chemistry and bacteriology of the process of decay.

Sewage Purification—PHELPS.

The Process of Decay.

Almost all known substances, whether inorganic or organic, possess the property of being more or less readily convertible into substances of a different chemical nature. The rusting of iron and the burning of wood are familiar examples.

The term stability is often used to describe the resistance which such substances offer to chemical changes. Thus, iron is obviously a more stable substance than wood, and, in general, the substances of the mineral world are more stable than those of the organic. Among the latter there is also a great difference in stability or resistance to change. Animal substances like meat are preserved only with difficulty, while wood decays but slowly and may readily be preserved indefinitely. We are accustomed to looking upon decay as a thing to be prevented as far as possible, but now our point of view must be reversed, for decay is the pathway by which unstable organic matter and waste products of life pass to the stable and harmless mineral form.

This process is chemical in nature as are all processes involving chemical change. Formerly, it was believed to be wholly chemical resulting spontaneously from the play of inherent chemical forces. Such a purely chemical reaction is typified in the rusting of iron. We now know that such a theory does not completely explain the facts of organic decay. Heat or preservatives will postpone the action in question indefinitely. Bacterial life is the essential factor and the chemical changes observed are only manifestations of the activity of these minute organisms. The latter are ever present, except where special means are employed to destroy them. In the air, in water and particularly in the soil they exist in countless numbers. Their food is the organic matter which they destroy, and their rate of multiplication depends almost wholly upon the food supply. Therefore, wherever organic matter is found, there, under natural conditions, will the bacteria be found also, and in numbers which are proportional to the amount and character of the food. The more stable forms of organic matter, such as wood, attract them but slightly; the more unstable or decomposable forms, such as meat, induce them to develop in countless numbers. Other elements must also be considered. Water is essential to bacterial life, hence the preserving power of dryness; and to some types of bacteria, air is important.

The process of decay then is merely a process of feeding by which bacteria consume decomposable substances and, in so doing, finally render them non-decomposable or stable. From a purely chemical viewpoint the process is analogous to combustion. The products are carbon dioxide and other volatile substances and a residue of mineral ash. The combustion may not be complete so that a residue may remain which is well charred but not completely burned. Such a residue has become less decomposable and, from the point of view of sewage disposal, may be sufficiently stable for practical purposes. This charred

Sewage Purification—PHELPS.

or partially stable condition will be referred to more in detail later in this discussion.

In brief then sewage disposal by biological methods is an application of the natural processes of bacterial decomposition or decay under conditions which are purposely designed to favor those processes and to direct them along the particular lines desired. The various types of sewage disposal now in use are the result of our attempts to direct these natural processes toward a particular end. We shall therefore consider these types, one by one, and learn if possible the specific object of each and the extent to which that object has been attained in practice.

Sewage Irrigation.

In the earliest days of the sewage problem relief was naturally sought along what may be called natural lines; that is, purification upon land which had not been especially prepared in any way for this purpose. This general type of process, which is known as "sewage farming" or "broad irrigation" is, even today, in use in many places and, under certain restrictions, gives admirable results. As the principles involved in this natural process of purification are identical with those which we shall meet with later in our studies of more recent types, it may be well at this time to study these principles in some detail. The natural power possessed by almost all soils to oxidize organic matter and render it inoffensive was shown to be due to the presence of certain specific organisms by Winogradsky about 1889. For the first time in the history of bacteriology, the specific bacteria responsible for this work were isolated and studied in pure culture in the laboratory. They have been named, as a group, the "nitrifying bacteria" because one of their chief functions in nature is the oxidation of nitrogenous materials to the form of nitric acid. About the same time, namely in 1890, Mrs. Richards and Prof. E. O. Jordan working then at the Lawrence Experiment Station of the Massachusetts State Board of Health, also isolated organisms of this group and showed that they were instrumental in the work of sewage purification. These nitrifying organisms require for their existence and activity an abundant supply of oxygen and a not too liberal supply of organic food. These scientific studies had great practical bearing upon the problem of sewage purification. It was known that the capacity of the soil to assimilate sewage was limited and that an overdose would result in the sickening of the soil and the temporary loss of its oxidizing powers. Now the explanation is obvious. An overdose of sewage deprives the soil of the atmospheric air which the bacteria require, and also supplies them with such an excess of food material that their normal functions are disturbed. We speak then of a sick filter or irrigation field in much the same way as we do of a sick man, meaning that the normal functions of such a field have been temporarily deranged under abnormal conditions of operation.

Under normal conditions, the activity of the organisms is

Sewage Purification—PHELPS.

sufficient for the complete assimilation and oxidation of the substances applied to the surface. The products of this activity are the oxidized forms of carbon and nitrogen, namely carbon dioxide and nitrous or nitric acids respectively. The former passes away as an inert gas, or perhaps is of some slight importance in the respiration of nearby plant life. The oxidized nitrogen compounds greatly enhance the agricultural value of the soil. By exactly this same process the manure and other nitrogenous fertilizers added to the soil are rendered available as plant foods. Therefore, it is readily conceivable that a combination of sewage disposal with agricultural uses of the soil might be made to advantage. This is the basis of the earlier attempts at sewage irrigation or sewage farming. The purified water carrying with it much of the soluble mineral matter resulting from the oxidation passes into the soil in the ordinary process of seepage and mingles with the ground waters below. Much of this water is also of service to the growing crops but at this point the conflicting interests of sewage disposal and agriculture appear. The former must go on day by day throughout the year, regardless of climatic conditions, and agricultural demands. The crops, on the other hand, require only a certain maximum amount of water. If this amount is supplied by nature a surplusage becomes a distinct disadvantage. Therefore in the operation of irrigation fields there is always a tendency to favor the growing crops at the expense of the sewage purification, resulting in the wasting of sewage at times of excessive rainfall. A second serious disadvantage of this otherwise admirable method, lies in the fact that at best only a limited amount of sewage may be applied to the fields. Even in dry weather when the demands of the crops are at a maximum, the sewage of about 100 persons per acre of land probably represents the maximum rate of application. A third and rather serious drawback, and one which has had no small influence upon the history of this method, is the possible relation which sewage irrigation bears to the public health. It goes almost without saying that vegetables which are commonly eaten without cooking should not be grown in this way. The more general position of sanitarians is that only fodder should be so raised, although corn for human consumption and, on our western coast, walnuts and almonds are being successfully grown upon sewage irrigated fields.

These various considerations and in chief those first mentioned relating to the life habits of the nitrifying organisms led early investigators to inquire how far the processes of nature could be improved under artificial conditions. The first result of this inquiry was the development in the early '90s of the type of sewage purification which for many years was universally recognized as the standard type, namely, the slow sand filter.

The Slow Sand Filter.

The sand filter differs from the older irrigation fields chiefly in the fact that a more careful selection of soil is made that better

Sewage Purification—PHELPS.

drainage is provided and that as a rule no crops are raised. These modifications result in supplying more air for the work of the organisms. This type of purification and all those which will now be described are known as "artificial methods of purification" in distinction from the natural method which we have just discussed. In all artificial methods more or less special preparation of the purifying machine is necessary. In the slow sand filter the first essential is suitable sand, the second, good drainage. For the best results sand having an effective size of from 0.2 to 0.4 millimeters is usually selected. At a depth of from 2 feet to 5 feet below the surface some system of drains, preferably agricultural tiles, is laid. It is essential for the successful operation of such a filter that it should dispose of its dose of applied sewage by absorbing it from the surface in the shortest possible time. The passage of this liquid into the interior of the bed forces ahead of it the air which was previously contained in the sand and draws after it a new supply of air from without. By the use of coarse sand and suitable underdraining, the amount of sewage which can be disposed of upon a given area is greatly in excess of that which can be treated on a natural irrigation field. In fact, this advantage is so great that taken in connection with the disadvantages of the older method, already pointed out, it has led to the development of slow sand filters almost to the complete exclusion of irrigation methods. The biological reactions involved in the two types are identical and the results of slow sand filtration owing to the control which can be exercised over the process and its freedom from agricultural demands, are very much superior to those of irrigation. Even in the matter of costs it has been learned that the value of the crops returned by the irrigation process is generally more than offset by the saving in land which necessarily is of considerable value in the neighborhood of cities. With this process, the sewage of from one thousand to two thousand persons can be satisfactorily treated upon an acre of land, thus increasing the efficiency of the land from ten to twenty fold over irrigation methods. The development of the slow sand filter made it possible to purify sewage from communities of a much larger size than had hitherto undertaken such purification, but at best left very much to be desired by the larger cities. It will be seen at a glance that the area of land required for even an average American city taken in connection with the high value of land located near such a city, would, of itself, make the cost of such treatment almost prohibitive. A second serious defect results from the fact that in many sections of the country, particularly through the middle west, suitable sand areas are not to be found, thus still further increasing the difficulty and the cost of installations of this type. Therefore the early development of sewage purification took place in the New England and North Atlantic States where sandy areas of glacial drift formation naturally abound, and until the art of sewage disposal had still further advanced along the lines of practicability and economy a great section of our country and most of our large cities were without any

Sewage Purification—PHELPS.

practical method of sewage disposal other than by discharge into the nearest stream. This state of affairs led to conditions almost intolerable in many instances. Streams which had in earlier times furnished satisfactory drinking water for large communities became so seriously polluted that their further use as a source of water supply had to be abandoned. Continuing pollution led later to the destruction of all major fish life and the incidental fishing industry, as well as the enormously important shell-fish industry. Finally with the rapid increase in populations many of our finest rivers have not only been robbed of much of their value and usefulness, but have become public nuisances, offensive to the senses of sight and smell, and a menace to the public health.

This picture is not in any way overdrawn and in the more densely populated portions of our country one need never go far in search of striking examples. Such conditions therefore naturally stimulated investigation into the further improvement of sewage purification methods, with the sole purpose in view of making it economically possible for the larger communities to deal with this serious problem of the public health and public comfort. These investigations, although less widely heralded than those of the decade previous upon sand filtration, have been of vastly more import in the development of sewage purification. In various countries they were made along differing lines and arrived at somewhat dissimilar results. To the workers in England, however, belongs most of the credit for the present practical developments in the sewage disposal problem. Three distinct and widely differing types of bacterial processes have resulted. They may properly be considered in the chronological order of their development.

The Septic Tank.

Hitherto our discussion of sewage disposal has been confined to that type of bacterial process in which air is an essential factor. Bacteriologists recognize two great groups of bacteria, the aerobic and the anaerobic, or those which require air in the life process and those which apparently do not. Probably all bacteria do require oxygen in one form or another and the difference between these two groups lies in their ability or lack of ability to utilize oxygen other than atmospheric.

The activities of these anerobic bacteria, those which live without air, are of especial value in certain methods of sewage treatment, which have in consequence come to be known as anaerobic methods. Chief among these is the septic tank process.

A septic tank is essentially a tight tank through which the sewage flows so slowly that most of the suspended solid matter either settles out or rises to the surface as a scum. The tank is therefore primarily a clarification tank, removing, by purely physical means, a large part of the solid matter carried in suspension in the sewage. Within this tank, however, and particularly in the accumulated sludge on the bottom, the anaerobic

bacteria thrive and multiply at an enormous rate. Working without oxygen these bacteria do not oxidize the materials upon which they feed, but in their endeavor to obtain the energy necessary to support their activities, they literally tear to pieces the complex organic material and reduce it to much simpler form. The distinction between this type of action and that which we have previously considered is crudely illustrated in the destruction of a wooden building. Complete destruction by fire in the presence of the air illustrates the work of the sand filter. Demolition by wreckers typifies the action of the septic tank. The material is all left but the structure is reduced to a heterogeneous mass of smaller structures which may be sorted and classified into a score or more of simple objects, such as boards, studding, sash, etc. In the septic tank there is little or no actual destruction or oxidation of material. The resulting product contains the original substance demolished into a score or more of simpler chemical substances which we call decomposition products. One chief characteristic of these decomposition products is their solubility. Where the larger and more complex molecules were insoluble and therefore constituted suspended matter, the products resulting are largely soluble and pass off in the clarified effluent. A certain fraction however remains in the tank as sludge and is not dissolved even after prolonged action.

The object of the tank is first to remove suspended solids and secondly to reduce the residual sludge to a minimum. Practical results vary widely in these respects. A well designed tank will remove from fifty to seventy-five per cent. of the suspended solids, depending upon the age and character of the sewage. Of the material thus removed and deposited upon the bottom, from thirty-five to eighty per cent., or more may be digested and returned to the effluent in a soluble form. The results are naturally intimately associated with the design. For efficient sedimentation velocities of flow should not exceed 0.1 feet per second, and distribution of the flow through a vertical plane should be nearly perfect. Many tanks are found to fail in respect to removal of solids through neglect of these factors, especially the second. If the distribution be imperfect the maximum velocities may be several times the mean, and eddy currents are produced which still further interfere with sedimentation.

On the other hand a good sedimentation tank often proves a poor dissolving tank. Tanks in actual practice often require cleaning annually and sometimes more frequently, but examples are not infrequent where they have operated for years without material increase in the accumulated sludge. There is no satisfactory explanation for these variations. It has been thought that certain sewages lack the necessary bacterial life to accomplish the result and the experiment has even been tried of inoculating a tank with material taken from a well-digesting cess-pool but without marked success.

In the writer's opinion this feature also is in part at least a matter of design. It is a well known biological principle that

the products of the vital activities of an organism are poisonous or at least detrimental to that organism. In the fermenting mass of sludge at the bottom of a tank there is necessarily an accumulation of the products of bacterial life. These products in turn tend to destroy the life which produced them. There is much evidence to support the view that auto-intoxication does take place in a tank. Fresh sewage sludge allowed to ferment shows a gradual reduction in bacterial numbers. Long period tanks, in which the products become more concentrated, are found to be less efficient in liquifaction of sludge than tanks having a shorter period of flow. If these views are correct, it follows that certain methods now being tried at Hampton, England, and at Essen, Germany, and well illustrated in the Imhoff tank, are not well adapted to sludge digestion. The purpose of these tanks is to concentrate the sludge in a separate sludge digestion chamber where it may have a very long period of digestion away from the circulating sewage. This idea is carried to the extreme in the design of the new disposal works at Baltimore. Here the accumulated sludge in the preliminary settling tanks will be removed at frequent intervals to special sludge-digestion tanks.

Acting upon the reverse view that the sludge should be digested in the presence of the flowing sewage so that the poisonous products would not accumulate to any extent, the writer is constructing small septic tanks upon the Dortmund plan, familiar in the older chemical precipitation processes. These tanks have a deep hopper-shaped bottom. The sewage enters near the point and flows upward at a constantly decreasing upward velocity, overflowing around the periphery at the top. This type tank has long been familiar as an efficient settling tank, but its use as a septic tank with the definite object of continuously washing the sludge at the bottom is novel. One such tank has been in operation at the Institute of Technology Sewage Experiment Station for over a year and recent examination and analyses of the contents indicate a digestion far more perfect than has hitherto been considered possible.

A matter of importance in any discussion of the septic tank is the question of its necessity in any given situation. There is a decided tendency on the part of engineers to regard a septic tank as a necessary part of any up-to-date sewage disposal plant wherever situated. Our experience in this connection however is restricted to European results and to the results in the smaller American communities. Leaving aside the Boston experiments for the moment, the city of Columbus, Ohio, is the largest city which has up to the present carried out a sufficiently prolonged series of investigations to determine whether or not a septic tank is required. The Philadelphia studies are not yet completed and the Baltimore investigations were not made upon the typical sewage of a large city. At Boston it was demonstrated that the crude sewage of the city was so finely divided by its long sojourn in large outfall sewers that septic tanks were not only unnecessary as a preliminary to trickling filters, but that better results as

Sewage Purification—PHELPS.

regards stability and non-clogging of the beds were obtained without them. For six years one trickling filter was run at a rate of two million gallons per acre per day without any internal clogging whatever. It is the writer's belief that the sewage of large cities, particularly with long outfall sewers, is in such a state of decomposition and its particles are so thoroughly disintegrated both mechanically and biologically, that in most cases purification may proceed without other preparation than that afforded by screens and detritus tanks. In smaller communities of course the beneficial action of the tank as a remover of sludge cannot be questioned.

The Contact Filter.

In the endeavor, previously spoken of, to increase rates of filtration, and during the period of development of the septic tank, investigations were being carried on along various promising lines in many places. Notable among these and by far the most important were those of W. J. Dibdin, at that time chemist of the London County Council. In 1892 Dibdin attempted to apply the principles of sand filtration under conditions which would permit of higher rates of application. For this purpose he employed coarse material, crushed stone or coke in place of the fine sand that had been used at Lawrence. It was necessary to prevent the rapid flow of sewage through these beds so they were made tight with an outlet that could be closed. The bed was filled completely with sewage, held in that condition for about two hours, slowly drained, and allowed to aerate for several hours; then the process was repeated. This type of bed came to be known as a contact bed from its mode of operation.

Dibdin's contact bed proved in reality to be a much more complex machine than the older sand filter. Extensive investigations have been made of the exact mode of action of this type of filter. It has been shown that there is an alternation of conditions within the bed corresponding to the cycle of operations. During the full period sedimentation and absorption are active. There are also secondary chemical reactions of an oxidizing character taking place between the fresh sewage and the oxidizing products of the last cycle. During the so-called resting or empty period a vigorous oxidation of the collected organic material is observed. The reactions are very complex and in the contact bed we have a type of purification differing greatly from any other. Probably no other single discovery in sewage disposal aroused so much interest, study or discussion. It was thought at first that a contact bed would not lose water capacity by "sludging up." This claim was both supported and contradicted experimentally but the final verdict seems to be that there is a loss of capacity, rapid at first but decreasing slowly, until the capacity becomes more or less constant at from 25 per cent. to 35 per cent. of its initial value. More than this cannot be stated with assurance. In some places a permanent equilibrium seems to have been reached while, in others, cleaning of the entire bed has been resorted to.

Sewage Purification—PHELPS.

Rates of application expressed in the usual form vary of course with the depth of filter. One application of sewage each day amounts to a rate of approximately 0.12 million gallons per acre per day for each foot in depth of bed. Beds may be operated at from two to four fillings per day. Three fillings probably represent an economical rate. At this rate of application a bed six feet deep would treat about two million gallons per acre per day, this being the sewage from about 20,000 persons. Greater depths are not usually practicable owing to the limited available head.

Mr. Dibdin's next development was a double contact system. The sewage was passed through a bed of coarse stone and later through one of finer material, for further purification. Excellent results are obtained by this means although rates are diminished one-half and the cost of treatment correspondingly increased. Triple contact systems have been employed with good results but poor economy.

The use of the septic tank in connection with contact beds has proven distinctly advantageous in European cities and in the smaller American communities. In this country at least contact beds are seldom or never operated without the tank.

A further advance in the contact bed principle, also due to Dibdin, is the so-called slate bed. Instead of using coarse broken stone, sheets of slate are laid in horizontal layers about an inch apart. These provide more liquid capacity than the stones. Recent reports from several installations in England indicate that as a substitute for primary contact beds or even for the septic tank these slate beds are admirably adapted. The effluent requires treatment in a secondary contact bed. In the discussion of this bed emphasis is laid upon the activity of worms and insect larvae in the body of accumulated humus material. It is believed that by this means much material is rendered innocuous.

The final effluent from a single contact bed is generally well oxidized and perfectly stable but as a rule it is turbid with suspended matter and has some odor. A double contact system can be made to yield an effluent which is almost clear. The results depend in large measures upon the care which is exercised in running the plant.

The Trickling or Sprinkling Filter.

Almost simultaneously with the development of the contact bed experiments were proceeding at other places in England along somewhat different lines, but with the same fundamental object, namely, to increase the possible rates of treatment upon biological filters. In 1892 Stoddard constructed a filter of coarse material designed to operate on the general plan of the sand filter but at greatly increased rates. Filters involving the general principle of coarse grained material run continuously at rapid rates were not at that time new. Experiments had previously been tried along these lines at Lawrence, Mass., by the late Colo-

nel Waring at Newport, Rhode Island, and by Lowcock at Malvern, England, but no results of permanent value had been obtained. Stoddard's experiments differed from those earlier ones chiefly in the higher rates that were attempted and in the fact that only natural aeration was employed. We may justly look upon these as the first satisfactory attempts to treat sewage by what we now know as the trickling filter process. The development of a mechanical distributor by Candy about the same time was of great practical influence in the history of this type of filter.

At about the same time also and independently, Corbett, Borough Engineer of Salford, developed a trickling filter after a series of investigations extending over several years. He first used the fixed nozzle type of distributor. Immediately following the publication of the work of Stoddard and of Corbett, experiments were made in many other places and the trickling filter process within a very brief period became one of the best known types of biological purification.

The trickling filter is virtually a very much enlarged or magnified sand filter. It is built out of crushed stone or other suitable material of sizes ranging from one-half an inch to 3 or 4 inches in diameter, although in most instances stone between 2 inches and 3 inches is employed. Not only is the size of the material larger than that employed in the sand beds, but greater depths also are found necessary. Trickling filters as shallow as four feet have been operated but present day practice dictates depths of from six to nine feet or over, as representing the greatest economy. In the method of operation, also, filters of this type resemble the older sand filters rather than the contact beds. The sewage is applied on the surface and allowed to trickle through the medium to the underdrains and final outlet without any attempt to hold it in contact with that medium for a longer time than is required for its unobstructed passage. The application of sewage, however, is essentially continuous rather than intermittent as in the case of the sand filter, and, owing to the size of the filtering medium, a uniform distribution of the liquid over the surface is quite essential. Liquid applied to the sand filter automatically distributes itself over the surface and even below the surface there is a strong tendency toward lateral distribution. In the trickling filter this is not the case. Hence the necessity for greater attention to this feature of the design, a point, in fact, upon which much of the success of the operation depends. In the chemical and bacteriological reactions involved filters of this type also resemble the sand filter rather than the contact bed. It was pointed out that the latter depended upon a somewhat complex and discontinuous series of reactions following the cyclic nature of its operation. The theory of the action of a trickling filter brings us once more to the old and simple theory of the oxidizing action of soils in general by bacterial activity. There is, however, one point of distinction between the two. The process involved in the sand filter and in the soil has already been likened to the complete combustion of organic substances, and at the same time mention was made of the fact that

it was possible to alter organic matter in a way which might be likened to charring rather than to burning. This illustration serves better than any other to describe the action of the trickling filter. There is, it is true, a certain amount of complete oxidation resulting in the formation of carbon-dioxide and nitrous and nitric acids, but the major portion of the organic matter applied to the trickling filter comes off from that filter sooner or later in a state which, judged by our ordinary chemical tests, is still organic matter. One important difference, however, is manifest at once. The substances leaving the filter have to a great extent lost their power to absorb oxygen from the surrounding medium and have a greatly reduced tendency to putrify. This condition is described as "stable," or "non-putrescible." Just as we have already seen mineral matters are more stable chemically than organic matters, so the latter differ among themselves to a marked extent. This class of organic matters which we have spoken of as having been "charred" or partially oxidized has a high stability factor and is allied chemically to the stable organic matter found in soils such as leaf mould. These substances are classed in general as humus matter, and the organic matter of a trickling filter effluent is also so classed. Stability as can readily be seen from this discussion is purely a relative term and nothing can be more misleading than the common practice of stating that an effluent is or is not stable. Such statements are based in general upon laboratory tests in which an arbitrary time and an arbitrary test for putrefaction are employed. The true measure of the work of any filter is not given under these conditions. It is easy to say that an effluent is good or bad basing the opinion upon some arbitrary line of demarkation, but such a classification fails utterly to identify an effluent just as it would to identify a man. It will be shown in a later section of this paper that absolutely good effluents although possible are seldom required. The whole tendency of modern sewage disposal practice is to obtain effluents that are good enough for the particular local requirements. Having this in view, the writer has elsewhere proposed a classification of effluents upon what is termed the "relative stability" basis. By this method with the help of a very simple test which can be carried out by any intelligent laborer (the so-called Methylene blue test) and by reference to a table of comparative values it is possible to ascribe to any given effluent a relative stability number which is a true measure of the actual degree of oxidation that the sewage in question has undergone. In this scale crude sewage would have a relative stability number of zero and a perfectly stable effluent of 100.

The trickling filter more than any other type of purification which we now have makes possible the treatment of the sewages of large cities. Rates of application as high as three million gallons, the sewage of thirty-thousand persons, per acre per day are already possible and our studies of various details of operation, particularly of the method of distribution over the surface, will doubtless eventually indicate ways in which even that rate

may be materially increased. A review of the work of the past twenty years in sewage disposal during which time rates have been increased from fifty or one hundred thousand to upwards of three million gallons per acre per day makes one hesitate to prophesy what the developments of the future may be, but it is worthy of comment at this time that during these years the art of sewage disposal has been developed to such a state that even our largest communities are now able to avail themselves of its advantages.

There has probably been more attention paid to the matter of distribution over the surface of trickling filters than to any other single feature in sewage disposal practice. In England the earlier forms of distributor were modeled after the familiar whirling arm lawn sprinkler in which the reaction of the issuing jet produces a revolution of the arm. Mechanical devices based upon this principle and upon various other ingenious hydraulic principles are in general use throughout England to-day. At Salford and at Birmingham there was later developed a type of sprinkler which has since come to be known as the fixed nozzle type. In sprinklers of this kind the liquid shoots fountainwise from nozzles or jets placed at or near the surface of the stone. There have been many developments of this type and in this country this general type of nozzles is universally used. The Columbus nozzle developed during the Columbus tests in which an inverted cone is placed immediately above the orifice and is supported by external arms and the Reading nozzle first used at the works at Reading, Penn., in which a similar cone is supported upon a spindle passing through the center of the orifice are two typical designs. An ingenious form of nozzle is one designed by W. G. Taylor and commonly bears his name. It distributes in a square periphery rather than in a circle. Mr. Taylor has also made a nozzle distributing in a hexagonal periphery. These nozzles have the considerable advantage of more perfectly covering the entire area without overlapping.

The use of fluctuating heads through such nozzles is also a recent development. The older idea was to produce a spattering effect by means of which a whole circle was wetted with more or less uniformity. It is difficult at best to obtain anything like uniform distribution over the wetted area by this means. Therefore attention has been turned toward producing a discharge in a narrow periphery or ring and to combine with this discharge a fluctuating head so that this ring shall move from the center to the outer circumference and back at more or less frequent intervals. It must be borne in mind in this connection that the rate of application at any one moment in such a method may be from ten to twenty times the mean rate. Therefore any long cycle of variation in which the discharge is concentrated in one periphery for a considerable period of time defeats the very object desired. The ideal method of employing a fluctuating head is to have the complete cycle so short that within a very short distance of the surface the downward flow of liquid through the medium is practically uniform.

Sewage Purification—PHELPS.

A type of distributor somewhat different from any of these described was developed some years ago at the experiment station of the Massachusetts Institute of Technology. This distributor has since come to be known as a "gravity" distributor by reason of its method of operation. The liquid is carried over the surface of the filter in a pipe or open conduit at hydraulic grade, and allowed to fall vertically through three-quarter inch openings and strike a slightly concave disc placed near the surface of the stone. It spatters from this disc leaving it in a slightly rising circular sheet which soon breaks into fine drops covering a circle of considerable area. This is a most successful distributor of a spattering type and yields more uniform distribution under constant head than any other. It seems to be particularly well adapted to small installations where the overhead troughs do not constitute a serious item of expense. Its ready accessibility for purposes of cleaning and the fact that the liquid passes through the last orifice or opening under a head of only a few inches thereby permitting a much larger orifice that is possible with distributors of the pressure type, together with its high efficiency under constant head, are its chief advantages.

III. MECHANICAL PROCESSES.

Modern sewage disposal must be regarded fundamentally as a biological process, but any discussion of the subject dealing with its biological aspects only would be incomplete. There are certain mechanical processes such as sedimentation and screening which are useful and almost universal adjuncts to biological plants. These will be discussed therefore with reference to the part they play in the whole process but not in great detail as to their various types.

Screens and Screening.

Screens were first used in connection with sewage to prevent the passage of large floating objects which might clog a pipe or a pump valve. In such a rôle they can hardly be classed as sewage disposal processes.

In connection with tanks and filters however it has been found within a very few years that fine screens properly cared for are of great assistance to the subsequent processes. It is possible in this way to remove a considerable percentage of the coarser suspended matter from the sewage and in that way to improve its physical characteristics with respect to subsequent purification. The removal of solids in this way serves a double purpose. The suspended solids of the sewage are objectionable first because they clog the filters and accumulate in the tanks, and secondly because being insoluble they must first be dissolved or disintegrated before they are in a physical condition to be purified. The screen removes this material in an unpurified condition and relieves the tank and filter of a definite amount of work. The other side of the matter must not be overlooked. The material

Sewage Purification—PHELPS.

removed must still be dealt with. This usually involves removal by farmers' burial or combustion in a near-by power plant.

This new use of screening as an adjunct to purification is distinct from the older use in protecting pumps and sewer lines. The distinction is perhaps best marked in the types of screens themselves. Screens of the earlier type were composed in general of parallel metal bars with openings of from one-half to three or four inches. They were cleaned by hand or by some simple mechanical rake. Screens of the other kind are most diverse in type but have in common a fine texture and some more or less complex mechanical method of cleaning. Perhaps the best example of such a screen is that used at Reading, Pennsylvania. A large cylinder, consisting of a steel frame supporting a coarse wire screen upon which a forty-mesh woven wire screen of a non-corrosive nickel-copper alloy is placed, revolves about an axis slightly inclined to the horizontal. The sewage enters the interior of this drum at the upper end and passes through the fine wire screen. The material removed is carried up one side of the drum and then washed off by a fine jet of water. A worm tends to make this material move toward the lower end while the revolution assists in that movement and also compacts the material by rolling it over continuously. The separation by this means is excellent and the solids leave the drum containing about 90 per cent. of water. They are collected in burlap bags and allowed to drain. Finally they are dried as completely as possible in a centrifugal dryer. It is stated that about 28 per cent. of the suspended solids are removed by this means, which makes the process comparable in efficiency with short-period sedimentation. This high efficiency is possibly due in part to the peculiar nature of the sewage of Reading. The manufacture of felt is an important industry of the city and the sewage contains noticeable quantities of fine fibrous material. This material is not only readily removed by screening but it forms an excellent felt filter for the removal of other materials.

This screen has been described in detail because it is one of the most successful of the numerous types proposed. An endless variety of revolving or moving screens, or of fixed screens with moving rakes or brushes, has been developed in Germany and England. Few if any comparative tests are available to determine the relative efficiencies of these. Comparisons of actual results upon different sewages obviously are of little value since efficiency must depend largely upon the characteristics of the sewage. So far as the somewhat meagre available data would indicate, none of the foreign installations are able to remove solids with anything like the efficiency obtained at Reading. Screens of the Reading type are being installed at other places and it will be of interest to note the results obtained upon other types of sewage.

Detritus Tanks.

Like screens, detritus tanks are employed primarily for the protection of certain parts of the sewerage system. Pumping

Sewage Purification—PHELPS.

machinery in particular, or such inaccessible parts of a system as inverted siphons, require special protection against sand and small stones. As in the case of screens also, detritus tanks have been found to have a certain field of usefulness as adjuncts in sewage disposal.

It is the purpose of such tanks to remove from the flowing sewage such material as fine sand, road detritus, and all heavier and coarser material. This material will settle out during a very brief period of detention, a few minutes only, and at velocities of flow only slightly under those found in the sewers themselves. A velocity of about 0.5 feet per second is sufficiently low.

In the design of a detritus tank, its function must be clearly borne in mind. Such a tank serves its fullest usefulness when it removes practically all heavy material, fine sand and stone and does not remove any considerable amount of organic material. A good separation at this point permits the comparatively simple disposal of a considerable portion of the total suspended matter, but if that material is mixed with sewage matter the advantages of the separation are lost. During four years of the Boston experiments the material removed from the detritus tank was spread upon the ground in the immediate vicinity of the laboratory building. No offensive conditions resulted. The amount and character of this material is shown by the following figures, representing average results for one year:

Pounds per million gallons of sewage.

Wet detritus, ...	1,600
Water, ...	430
Clean stone, etc., ...	190
Fine dry material, ...	970
Mineral material, ...	864
Organic material, ...	106
Organic nitrogen, ...	2.2
Organic carbon by permanganate, ...	0.2

It is evident that such material, representing in this case about one-third of the total suspended matter of the sewage, is entirely innocuous in character. Its removal greatly assists the subsequent processes and the possibility of disposing of it by dumping in any convenient place reduces the sludge problem of the septic tank or the clogging problem of the filters to a marked extent. The true functions of a detritus tank as an adjunct in sewage disposal is therefore the separation of that portion of the suspended solid which requires no special disposal if properly separated from the true sludge.

When separate sewers are provided for the surface drainage and the disposal plant deals only with the flow of sanitary sewers there is less need of such a tank. Even in such cases, however, it has a certain usefulness.

Plain Sedimentation.

The storage of sewage in tanks for the removal of a part of the suspended solids is resorted to at times chiefly as a preliminary treatment. Before the septic tank became known as such, sedimentation with or without the addition of chemicals was a common method of clarification. When the action was not assisted by the addition of chemicals the process was called "plain sedimentation." A septic tank is primarily a sedimentation tank in which the sludge is allowed to accumulate and decompose. If the sediment be removed at intervals sufficiently frequent to prevent any active fermentation we have a typical sedimentation process. Experience has shown that in from four to six hours about 80% of the suspended solids are deposited from a quiescent body of sewage and that the deposition of a further amount is extremely slow. Mathematically it can be shown that the rate of deposition is a logarithmic function of the time and experiments made at Cologne by Steurnagle gave a curve of deposition in practical agreement with that derived from theory. The lighter and smaller portions of the suspended matter therefore cannot be removed economically by this means. Results in liquids moving horizontally with velocities less than 0.1 feet per second are practically as good as those obtained in quiescent liquids.

In a sedimentation process there is no liquifaction of the sludge and consequently the volume of sludge produced is greater than in the case of the septic tank. In the latter there may be an accumulation of from one-half to one and a half cubic yards per million gallons of sewage; in the sedimentation tank the amount will approximate three times as much.

A new use of sedimentation tanks has been introduced of late, due, in part to certain claims to proprietary rights in the septic tank, claims which have for the present been sustained by the courts. At Baltimore and elsewhere it has been proposed to settle sewage in preliminary sedimentation tanks and to pump the accumulated sludge to liquifaction tanks for further decomposition. Technically neither of these tanks by itself is a septic tank as defined by the court. Aside from this possible use of plain sedimentation as a substitute in part for a septic tank the older process has practically disappeared.

Sedimentation is often a valuable and necessary after treatment, following filtration through trickling filters. The effluent of such a filter is frequently as turbid and as high in suspended solids as the raw sewage. This material is fairly well oxidized and stable but it is unsightly and would cause deposits in slack water. It settles rapidly so that a two hour period of sedimentation is found to remove from 60% to 75% of this suspended matter.

IV. CHEMICAL PROCESSES.

In the earliest days of sewage purification the natural limitations of sewage irrigation, coupled with a full appreciation of the economic advantages of returning the wastes of life to the soil,

led to numerous investigations of the possibility of recovering from sewage a dry product having commercial value as a fertilizer. These investigations led to a large group of methods known as chemical precipitation methods. In England alone, previous to 1876 over 400 patents covering processes of this kind were issued. It required the expenditure of large sums of money and over twenty years of experimental study to demonstrate that, with the methods then available at least, the recovery of valuable ingredients from sewage could not be carried on as a profitable enterprise; aside from its commercial aspects however and merely as a method of purification, chemical precipitation made for itself a broad field, and in many instances even down to the present day the recovery of nitrogenous material has been undertaken to partially offset the cost.

With our ever-increasing demands for nitrogenous fertilizer material and an apparently dwindling supply of nitrogen in available forms, it does not seem at all improbable that, in the near future, we may once more take up that problem. It is merely an economic question. When the increasing value of nitrogen as a fertilizer meets the decreasing cost of its recovery by improved methods, then recovery will undoubtedly be practiced. Signs are not lacking that this time is near at hand.

As a corollary to chemical precipitation there came the idea of purifying chemically, both by oxidizing the organic matter and by killing the germ life. All attempts at the chemical oxidation of organic matter even when restricted to the destruction of odors, were signal failures, or at least gave but temporary relief. The use of manganates and of bleaching powder as deodorants was attempted upon the River Thames with imperfect success.

The idea of chemical disinfection or sterilization however was never completely lost sight of and in recent years, when its proper field of usefulness was recognized, it took rank as one of our most valuable methods of sewage treatment.

For our practical consideration, therefore, we have two types of chemical process at the present day, precipitation and disinfection.

Chemical Precipitation.

The chemical precipitation of sewage involves in general the addition of two chemical substances which, by their mutual reaction, produce a voluminous and flocculent precipitate. This precipitate is allowed to settle in a suitable tank, and in so doing it drags down with it a large part of the suspended matter. Despite the numerous patented processes of former years, the only process employed to any extent at the present time is the iron-lime process. Crude sulphate of iron in solution is first mixed with the sewage and then an emulsion of slacked lime is run in. There results a precipitation of ferrous-hydroxide and sludge which is deposited in settling tanks. The sludge removed from these tanks is then disposed of by running upon land, filter pressing, or, in many European cities, carrying to sea in scows.

Sewage Purification—PHELPS.

At Worcester, Massachusetts, where this process has been in operation for twenty years, the rolling mills discharge sufficient iron salts into the sewage to make it unnecessary to add more at the works. Here the sludge is pressed in filter presses and used in filling low land. The large amount of lime which it is necessary to use together with the iron compounds present, destroy the value of the product as a fertilizer. Eight hundred and seventy-one pounds of lime are added to each million gallons of sewage treated and 2900 pounds of solids, reckoned upon a dry basis, are recovered. At Providence, Rhode Island, a similar plant was installed in 1902. Six hundred and six pounds of lime are added to each million gallons here, and 2,140 pounds of dry solids are recovered. They are carried off by boat.

Chemical precipitation at best merely clarifies the sewage and the process is to be looked upon in general as preliminary to further treatment. Except under peculiar local conditions the expense of operation is so great that it has at present a very limited field of usefulness.

A recent development in chemical precipitation, looking again toward the recovery of valuable products, is due to Dr. William McMurtrie, of New York City. In this process commercial mono-calcium phosphate is used with lime to form a precipitate of the dicalcium phosphate. This latter has a distinct advantage over the iron precipitate in that it passes from an amorphous to a crystalline condition and hence is much more readily and cheaply handled and filtered. It is claimed also that it has greater powers of absorbing soluble organic nitrogen from the sewage. Its particular advantage however lies in the fact that the addition of iron, so undesirable in a fertilizer, is unnecessary. The phosphate would be prohibitively expensive were it not for the fact that an almost complete recovery is possible. The phosphate added has of course a value in the final product equal to its initial cost.

Chemical Disinfection.

It has been shown that chemical disinfection grew originally out of the general chemical treatments that were so common twenty-five years ago. At first the aim was to prevent the putrefaction of sewage by chemical means. Temporary benefits only were derived but as these often lasted until the sewage was well on its way in the stream much credit was given these various processes. Electrical processes in particular, whereby the desired chemical substances were made by electrolytic action, became very popular at one time. Gradually the views of the English sanitarians became sounder and these processes of chemical treatment were recognized as being in opposition to the activity of the natural purifying agents and hence undesirable. For many years thereafter nothing more was heard of sterilization or electrolytic sewage purification.

A new interest has been aroused in the problem by our increasing knowledge of contagious diseases and especially of the relation of sewage polluted waters to those diseases. Sewage

purification, it is true, is not accomplished by the mere destruction of all germ life, but the proper disinfection of sewage will prevent the spread of infectious material contained in it. This aspect of the matter was realized in Germany and in England some years ago and experiments were made at both Berlin and Hamburg and by Rideal in England. The subject reached its greatest practical development in this country through experiments which were conducted at the Sewage Experiment Station of the Massachusetts Institute of Technology and later on a practical scale at Red Bank, New Jersey, by the State Sewerage Commission, and at Baltimore by the Baltimore Sewerage Commission. In all of this work financial aid was received from the United States Geological Survey, so that Federal, State, and City governments and an educational institution were interested. All this work was under the writer's charge. It was demonstrated that the disinfection of sewage filter effluents as precautionary means against the pollution of water supplies and shell fish, was not only highly desirable but entirely feasible; that under certain conditions crude sewage might with advantage be disinfected and discharged without further treatment; that the cost of this treatment was less and the efficiency greater than had hitherto been shown; and that of all possible chemical or electrical methods, calcium hypochlorite was by far the most efficient calculated upon a cost basis.

This chemical substance is the active constituent of commercial bleaching powder or "chloride of lime." Bleaching powder is an impure commercial product manufactured in large quantities abroad by some of the earlier chemical methods, and in this country at Niagara by modern electrolytic methods. Owing to the fact that in the latter case it is essentially a by-product of the much more important caustic soda industry, its present market price is very low, in fact less than the cost of production on a small scale. Upon admixture with water it goes into solution only partially, a residue of carbonate of lime and an excess of free lime remaining in the tank as a white sludge. In practice at the larger works it is desirable to keep this mixture stirred up and to discharge the sludge with the solution; at smaller works economy indicates the use of the clear solution and the disposal of the lime sludge in a convenient manner. The strength of such a solution as determined by chemical analysis is reported in terms of "available chlorine" and this convenient term may be retained for purposes of discussion. To the layman, one of the most striking features of this process is the relatively small amount of disinfectant necessary. For average crude sewage an amount of so-called "available chlorine" equivalent to about five parts per million parts of sewage, which amounts to about 125 pounds of bleaching powder per million gallons, suffices. Upon the present market price of \$25 per ton or less, it will be seen that the cost of bleaching powder necessary will be in the neighborhood of \$1.60 per million gallons of sewage disinfected. By the use of the quantity indicated, disinfection is accomplished within a very few minutes, and storage periods of not over thirty

Sewage Purification—PHELPS.

minutes are ample. Sewage stronger than the average American sewage would require somewhat larger amounts than these indicated, but twice the quantity probably represents the maximum. For partially purified effluents, such as those resulting from trickling filters, lesser quantities are sufficient. At Baltimore three parts per million of available chlorine, or 75 pounds of bleaching powder per million gallons, were found effective in the disinfection of the trickling filter effluent. At Boston satisfactory disinfection of a similar effluent was accomplished through a period of six months by the application of three and a half parts of available chlorine. Effluents of a higher degree of purity can be disinfected with corresponding smaller amounts. The total cost of the process, including interest charges and depreciation upon the necessary fixtures, labor, and other items, will range from \$1.00 or less in the case of effluents to about \$3.00 in the case of crude sewages. These details are given in the accompanying table. The results, which have been described as satisfactory, are numerically expressed by removals of the total bacteria, averaging, 97 per cent. in the case of effluents and 99 per cent. or more in the case of crude sewage. In the former case the combined efficiency of the filter and the disinfection will bring the figure up to 99 per cent. or more. Special studies have also been made in this connection to show the probable effect upon typhoid fever germs as compared with the effect upon the total bacterial content. The indication has been that the former are affected to fully as great an extent as the latter. They are probably more completely removed.

ESTIMATES OF THE COST OF OPERATION OF A PLANT FOR DISINFECTING SEWAGE OR EFFLUENT WITH CHLORIDE OF LIME, BASED ON A CAPACITY OF 5,000,000 GALLONS A DAY.

Available Chlorin, Parts per Million.	Bleach, Pounds per Mil. Gal. (Apprx.)	Time of Contact, Hours.	Cost per Million Gallons.					Total.
			Fixed.		Operating.			
			Storage Tanks.	Other Fixed Charges.	Bleaching Powder	Labor.	Power.	
1.....	25	5.0	\$0.10	\$0.02	\$0.30	\$0.10	..	\$0.52
2.....	50	2.5	0.5	.04	.60	.10	..	.79
3.....	75	1.6	.04	.05	.90	.10	\$0.02	1.11
4.....	100	1.2	.03	.07	1.20	.10	.02	1.42
5.....	125	0.8	0.3	.08	1.50	.10	.03	1.74
10.....	250	0.5	.02	.16	3.00	.15	.06	3.39
15.....	375	0.5	.02	.24	4.50	.20	.09	5.05

V. ENGINEERING FEATURES. CLASSIFICATION OF PROCESSES.

To preserve a logical development of the theory of sewage disposal we have thus far considered the various types of process

Sewage Purification—PHELPS.

grouped according to their natural relationships and order of development. For the more practical purposes of the engineer a classification should show the actual working relationship of each process to the others and to the whole problem. For this purpose a tentative arrangement may be made as follows:

Preliminary Processes:

- Screening,
- Removal of detritus,
- Sedimentation,
- Chemical precipitation,
- Septic tank treatment.

Major Processes:

- Sand filtration,
- Treatment in contact beds,
- Treatment in trickling filters.

Finishing Processes:

- Secondary filtration,
- Sedimentation,
- Chemical disinfection.

It must be stated at the outset that this arrangement is not rigid; that a preliminary process may at times be a final one; and that a complete working plant may be made up of one or more units selected from any of these groups. This classification, then, merely shows the usual order of arrangement of the various units of a plant when that plant is composed of several units, and places our types in convenient order for a discussion of their engineering features.

The first and most important problem which confronts the engineer is that of selecting out of this long list of types, and its almost infinite number of modifications, the particular combination of processes best adapted to his special requirements. On this point expert knowledge is of more vital importance than upon any other point of the work. In what follows, therefore, it is not the purpose to lay down any general rules for the selection of a type of disposal works, for such an effort would not only be futile but naturally misleading and harmful. It will rather be the purpose to indicate the more important factors which enter this problem in order that its complexity shall not be underestimated nor its difficulties unappreciated.

Selection of a Process.

A complete knowledge of the local situation is an essential prerequisite to the proper design of purification works. Cure-alls in sewage purification are equally impossible and unnecessary. To accomplish the desired result with the minimum of expense and effort is the purpose of modern sewage purification practice and the more thorough-going and scientific the initial study of

the situation, the more satisfactorily will that purpose be achieved. Approximate methods of solution may be satisfactory in that they are sufficient but they often lack that other essential of correct engineering design, necessity. To accomplish enough and not too much, in the case of large works in particularly, may mean the difference between practicability and impracticability. No two situations are ever exactly the same but each, upon analysis, is found to be the sum of a number of elementary conditions common to all but varying in their relative importance from case to case. A brief consideration of the nature of these elementary factors will, therefore, aid one to understand the method of solution.

The most important factor in any given problem is the nature of the sewage itself. This is a matter that requires experience rather than knowledge for its full appreciation. Among the more evident causes of variation may be mentioned the amount of storm water to be dealt with, the character and relative amounts of waste waters from the various manufacturing industries, and the concentration of the sewage matter as determined, primarily, by the daily flow of sewage per capita of contributing population, and, secondarily by the habits of the community. Less obvious but equally important factors determining the characteristics of a sewage are what are termed the condition factors. Independent of the initial make-up of the sewage, its condition, as determined by the density of population, size, slope and length of the sewers, average temperature of the sewage, and other similar facts, must receive separate consideration. It is becoming more and more apparent that these rather obscure condition factors have hitherto received too little attention, and that this oversight is responsible for the frequent failure of plants which are exact duplicates of other plants in successful operation. These facts explain also, in large measure, the very diverse results which are obtained upon apparently quite similar sewages by the same methods of treatment, and even upon the same sewage at different seasons of the year.

It is not possible at this time to describe more fully these characteristics of a sewage in their relation to the design of works. The first group are determined by a study of the system. They readily suggest in each case the modifications in the general plan which they necessitate, such as alteration of the rate of treatment to accord with the strength of the sewage and special treatments determined by the special nature of the manufacturing wastes. The second group of factors, the condition factors, are more difficult even to determine. Our newer methods of analysis based upon the so-called putrescibility of the sewage, that is its relation to oxygen, give us information along the desired lines, and experience is gradually working out the relation between any given condition and the most efficient treatment.

Turning our attention now to the other side of the pollution problem, we usually find a body of water with its own special characteristics. These too are so diverse that no two cases are alike but here again we may analyze the situation into a combi-

nation of a few prime factors. Nuisances are produced in a stream in three principal and independent ways. Any one, any two or all three may be involved in the case in hand.

First and most important, from a sanitary point of view, we may have bacterial pollution. Whether or not such pollution should be prevented in the case in question may be open to debate and we have already touched upon the principles involved. It is an economic question pure and simple. The pollution of a stream by sewage interferes with its use for purposes of water supply and for other useful purposes. Assuming that bacterial pollution is undesirable sewage purification methods are now available by which such pollution can be prevented. These have been described under disinfection. It should be noted also that every advance in purification methods re-opens the original discussion upon purely economic grounds by supplying new facts in evidence. Given a sufficiently inexpensive process of purification and there would be no economic argument. This is strikingly the case with the newer processes of chemical disinfection. These make it possible to destroy germs at a very low cost. At once it becomes possible to protect shell-fish areas which otherwise would not justify the larger expense entailed. In this way the question as to whether a stream is to be given over to the carrying off of wastes and sewage or to be preserved for more useful purposes is profoundly modified with each advance in purification methods. In the light of our present knowledge, also, disinfection methods should be looked upon as essential after-treatments in any purification project undertaken for the protection of a domestic water supply. Few, if any, purification works produce effluents that cannot be improved bacterially by such treatment at a cost that is negligible with respect to the total cost of treatment and to the improvement obtained.

From a purely physical standpoint streams and other bodies of water may be injured in two ways by the discharge of untreated sewage. These two kinds of injury correspond to two characteristics of the sewage. The first follows from the so-called suspended matter, that is impurities of whatever kind that are not dissolved. Such material accumulates upon the banks and bottoms of sluggish streams or forms an unsightly and disagreeable floating scum. In small streams, that are dammed for water power, deposits will occur in the slack water. By subsequent fermentation, such deposits may give rise to conditions in the waters above which indicate more serious conditions of pollution than actually exist. A case has recently come to the writer's notice in which an existing small but continuous pollution could be amply cared for by the available flow of the stream, without the production of any physical nuisance, if the material were carried away continuously and completely; but, owing to deposition and long accumulation, a nuisance of the kind next to be described, was produced, which would not have followed the direct application of ten times the amount of polluting matter under conditions which prohibited such deposition. This matter of the suspended solids therefore, is the second independent

Sewage Purification—PHELPS.

factor in sewage purification. For its special treatment we have screens, sedimentation, chemical precipitation, and the septic tank. These devices are primarily designed to handle this particular kind of material. Other methods of treatment involve it partially and incidentally. It is not often that the suspended matter represents the whole problem, but when it does one or more of the above processes may be considered a complete solution. More frequently the two classes of nuisances which we have dealt with are combined in one case. This happens chiefly in the case of salt-water discharge, where the protection of bathing beaches and of shell-fish areas demands a combination of bacterial purification with removal of solids. In most cases however further treatment is called for and the methods for the removal of solids assume their conventional position of preliminary processes. In classifying them as such the real part they play in the whole scheme and the possibility of their independent use must not be overlooked.

A third possible nuisance arising from sewage pollution is due to the power of the sewage matter, either dissolved or suspended, to putrefy and to rob the water of its dissolved oxygen. Normal waters dissolve from the atmosphere a definite amount of oxygen, which enables them to support fish life and, by the aid of bacteria, to oxidize small amounts of organic matter. This action is similar to that observed in the soil and it is this self-purifying power of a stream that is relied upon, generally with over-confidence, to deal with the sewage problems of most of our communities. It is strictly limited and a scientific study of its scope and limitations is one of the most pressing needs of the sewage disposal problem to-day. Our present knowledge is based upon observations of cases in which the effect of suspended matter deposited upon the bottom of a stream is confused with the more pertinent question of the ability of a stream to deal with and oxidize material which is carried off continuously. It has already been shown how the former effect may completely mask the latter. Here again studies along the newer lines of sewage chemistry, involving determinations of the oxidizability and putrescibility of sewage in its various conditions are of greatest service. The present indications are that the self-purifying powers of streams have been wasted through misuse and that a thorough knowledge of the subject will result in greatly enhancing their economic value and at the same time diminishing the evil results now so much in evidence. With the advent of methods of disinfection by which the bacterial pollution may be dealt with as an independent problem, it becomes all the more necessary to develop to the fullest extent the possibilities of purification in the stream. The major purification processes of our classification serve primarily to lessen the burden which is imposed upon the stream as an oxidizing machine. These processes are mere oxidation, as has been shown. They decrease the putrescibility of the sewage and, in consequence and by the same measure, relieve the stream of a definite amount of work. To determine the amount of such relief called for in any case,

Sewage Purification—PHELPS.

and the exact point to which self-purification in streams can be economically extended, involves investigations differing fundamentally from any that have hitherto been made. Investigations of this kind are most urgently called for at the present time and will doubtless be made in self-defense by some of our larger cities in the near future.

On the other hand, looking upon artificial purification as an adjunct and aid to this more fundamental process, and not as a mere imperfect imitation of the old-fashioned sand filter, it is probable that greater advances in the economic oxidation of sewage will be recorded in the future than have ever been achieved in the past. No justification is here attempted for the present gross misuse of inland waters. What is advocated is a policy of conservation rather than of wasteful destruction of a natural resource of inestimable value.

In brief summary then, we have as independent factors in stream pollution upon which to base the design of purification works:

Bacterial pollution with its remedy in chemical disinfection.

Physical nuisance arising from the deposit of solids upon the banks and beds of streams or other waters, with its remedy in the so-called preliminary processes, screening, sedimentation, with or without the assistance of chemicals or septic action, and;

Physical nuisance arising from an overloading of the oxidizing powers of a stream with its remedy in one or the other of the so-called filtration processes or major processes of purification, or in some improved method of oxidation.

The indiscriminate application of any of these processes or of any combination of them will, in all probability, accomplish either too little or too much, or most likely of all, will accomplish that which is not necessary and leave undone that which is required.

The Cost of Sewage Purification.

Any attempt to lay down general principles regarding the cost of sewage purification would be futile and misleading, while a discussion of this subject without any reference to costs whatever would be purely academic. Under the circumstances the best that one can hope to do is to review certain experiences of works already constructed, to analyze the conditions obtaining, and to indicate what the costs of purification have been in existing works of the various types that have been discussed. Such a summary is at least historically valuable. In the hands of engineers of experience deductions may also be made which have some value in preliminary studies. Where the total cost is mainly one of operation, as in the chemical processes, the results of experience are more directly applicable.

The most serviceable basis upon which to compare costs of sewage purification for purposes of comparison is the "per-

Sewage Purification—PHELPS.

capita per-annum" basis. The cost per million gallons treated is affected by the rate of water consumption since it is easier and cheaper to purify a weak sewage. Costs calculated per acre of filter and upon other bases have similar objections. When complete data of both construction and operation costs are available the total cost per annum is properly determined by adopting a forty year depreciation basis for the permanent work, and a twenty year basis for machinery, piping, etc., and providing an annual interest and sinking fund charge which will pay interest upon the total investment and rebuild portions of the works at the expiration of the assigned depreciation period. For purposes of uniformity a 5% interest and depreciation charge is made in this summary. To this interest and sinking fund are then added operation and maintenance charges and incidental expenses. This total annual charge may then be divided by the contributing population to determine the cost upon a per capita per annum basis. In many cases, operating expenses are not available. As these are much more constant than construction costs the fewer figures that are available are as fully applicable.

A special item which often enters the disposal works estimate is pumping. Where additional pumping is made necessary in order to obtain head for the operation of the works, as is generally the case, this pumping item is a just charge against the process, but obviously, for purposes of comparison, it should be omitted from the general tabulation and estimated if desired as a separate item. Pumping sewage costs all told from twenty-five cents to two dollars per million gallons raised one foot. The cost depends primarily upon the amount to be handled, but in part also upon the regularity of the flow and the efficiency of the machinery and of the administration. Under exceptionally favorable conditions as to modern equipment and careful supervision, pumping at the Metropolitan Works, Boston, Mass., averages about \$0.08 for capital charges and \$0.12 for operation and maintenance per million-gallons-foot. These are exceptionally low costs.

The same variation is met with in regard to land, an item entering largely into the cost of sand filters in particular. In Massachusetts the average cost of land used for filtration has been \$120 per acre amounting in interest charges to less than one cent per capita per annum. Even with trickling filters near large cities the land costs are no inconsiderable part of the total. These however are omitted from the following summary and must be supplied in each case.

The data upon which the summary of costs is based have been obtained from various sources, most of which are sufficiently identified by the citation of authority in the last column and by the appended table of references. The figures for Ocean Grove and Newton, N. J., and for Ravena, Ohio, were privately communicated to the writer by Mr. Clyde Potts, who designed these plants.

Among the preliminary processes the costs of screening are of first interest. These costs are practically confined to costs of

operation. In Boston imperfect screening through old-fashioned basket screens, costs for labor about six cents per million gallons, although twice the volume of sewage could be screened at practically the same cost.

More perfect screening by screens of the newer type is estimated to cost at Reading about 40c per million gallons or 1.1c per capita per annum. This is exclusive of a small charge for water which will vary from place to place.

The costs of constructing and operating septic tanks are not often estimated separately. From various sources it has been possible to separate these costs from the total cost of works. The costs expressed in our present units vary from 1.67 to 6.5 cents for capital charges and from 0.3 to 3.8 cents for operation, averaging 3.4 cents and 2.7 cents respectively. Chemical precipitation costs, for operation alone, 36.2 cents at Worcester, Mass., and 25 cents at Providence. The capital charges at Worcester are somewhat difficult to fix owing to the age of the plant. They are approximately 14c, making a total cost of 52c per capita per annum.

Coming to the major processes, sewage farming, of course, may show a profit or a loss depending entirely upon local conditions. In Southern California very satisfactory returns are reported from fruit and nut orchards.

In slow sand filtration as usually practiced upon land of low value the costs are usually low. That great variation may exist in these is shown by figures published by the Massachusetts State Board of Health in reference to fifteen Massachusetts plants. The average cost, including the capital charges and cost of operation, has been calculated upon the basis of total costs and total contributing population. It is 38.8 cents. Individual costs vary from 26.2 cents to \$1.27. At Brockton, the largest plant in the State, it was 24.2 cents. Bearing in mind the large areas of land required for this process one sees that sand filtration is by no means one of the cheapest processes of purification available. The new sand filter plants with septic tanks at Newton, N. J., cost for capital charges 39.0 cents and at present the total operating costs are given at 22.4 cents. At Saratoga Springs the total cost of tanks and filters, exclusive of pumping machinery, amount, at 5% to 7.9c and operation to 4.3c. Hering's estimate for tanks and filters for the Calumet District, calculated to our present basis of comparison and excluding pumping is, capital charges 21.8c, operation and maintenance 45.1c., total 66.9c. Altogether the total costs including capital charges and operation vary from 12.2 to 74.9 cents and average 51.8 cents. The costs of contact filters are seen to be within the same range of values.

Trickling filters are so new in this country that there is little available data upon their costs. Gregory in an excellent analysis of the Columbus costs shows the total construction cost of tanks and filter with all accessories to be \$22,820 per million gallons daily capacity. The plant is designed for a population of 200,000 and at full development the capital charges on these works will

Sewage Purification—PHELPS.

amount to about 11.4 cents. Hering's estimate for the Calumet District for septic tank, trickling filters and supplementary sedimentation tanks but exclusive of pumping, given in our present unit, are capital charges 22.8 cents, operation and maintenance 16.2 cents, total 39 cents. Hazen's estimate for Patterson, N. J., included separation of storm water and pumping in addition to septic tanks, supplementary sludge digestion tanks, sprinkling filters, final settling basins and an allowance for cleaning the filters after fifteen years. Without attempting to separate these capital charge items they amount in toto at 5% to 80 cents per capita per annum. Operation and maintenance of the purification works alone come to 38 cents or a total of \$1.18 which would in reality be materially reduced by the proper deduction of part of the capital charge.

Average costs are 17.7 and 22.1 cents for capital charge and operation respectively, excluding the former item on the Patterson estimate.

The costs of disinfection with bleaching powder have already been given in a general way. They depend primarily upon the character of the sewage or effluent treated. For a septic sewage the total cost is about 13.7 cents and for a well purified trickling filter effluent 4.4 cents per capita per annum. The cost of disinfecting crude or screened sewage will lie between these two figures while for more highly purified effluents the cost will be even less.

These costs are summarized in the table on page 479.

REFERENCES TO TABLE OF COSTS.

- Arnolt, F. M., *Thesis, Mass. Inst. Tech.*, 1910.
Barbour, F. A., *J. Ass'n Eng. Soc.* XXXIV, 1905, 33.
Fuller, G. W., *Trans. Am. Soc. C. E.*, XLIV, 1905, 147.
Gault, M., *Am. Rep. Supt. of Sewers, Worcester, Mass.*, 1909.
Gregory, J. H., *Trans. Am. Soc. C. E.*, LXVII, 1910, 312.
Hazen, A., *Report to Paterson, N. J.*
Hering, and Fuller, G. W., *Eng. News*, 57, 1907, 128.
Hering, Stearns, & Grey, *Report to Baltimore*, 1906.
Mass. Report of State Board of Health, 1903.
Phelps, E. B., *U. S. Geological Survey, Water Supply Paper*, 229, 1909. •
Potts, C., *Privately Communicated*.

Sewage Purification—PHELPS.

Costs Dollars per Capita Per Annum.

Place.	Process.	Capital Operation and Charges.	Maintenance.	Total.	Authority.
Boston, Mass.	Rough Screening.		.0016		Met. W. & S. Bd.
Reading, Penn.	Fine Screening.		.011		Arnolt.
Saratoga Springs, N. Y.	Septic Tanks.	.0194			
Chicago, Ill.	Septic Tanks.	.046	.038	.084	Hering.
Columbus, Ohio.	Septic Tanks.	.0167			Gregory.
Baltimore, Md.	Septic Tanks.	.023	.039	.062	Hering, Stearn, Grey.
Ocean Grove, N. J.	Septic Tanks.	.065	.003	.068	Potts.
Worcester, Mass.	Chemical Precipitation.	.140	.362	.502	Gault.
Providence, R. I.	Chemical Precipitation.		.250		Fuller.
Brocton, Mass.	Sand Filters.				
*Massachusetts Towns.	Sand Filters.	.230	.158	.388	Mass. B. of H.
Baltimore, Md.	Septic Tanks and Sand Filters.	.372	.377	.749	Hering, Stearn, Grey.
Newtown, N. J.	Septic Tanks, Sand Filters.	.388	.224	.612	Potts.
Ravenna, Ohio.	Septic Tanks, Sand Filters.	.225	.135	.360	Potts.
Saratoga Springs, N. Y.	Septic Tanks, Sand Filters.	.079	.043	.122	Barbour.
Chicago, Ill.	Septic Tanks, Sand Filters.	.218	.451	.669	Hering.
Worcester, Mass.	Sand Filters.	.348	.380	.728	Gault.
Chicago, Ill.	Septic Tanks, contact Filters.	.333	.272	.605	Hering.
Auburn, N. Y.	Septic Tanks, contact Filters.	.120			
Johnson City, Tenn.	Septic Tanks, contact Filters.	.292	.183	.475	Potts.
Columbus, Ohio.	Septic Tanks, Trickling Filters.	.114			Gregory.
Washington, Pa.	Septic Tanks, Trickling Filters.	.143			Pratt.
Chicago, Ill.	Septic Tanks, Trickling Filters.	.228	.162	.390	Hering.
Baltimore, Md.	Septic Tanks, Trickling Filters.	.224	.121	.345	Hering, Stearn, Grey.
**Patterson, N. J.	Septic Tanks, Trickling Filters.	.800	.380	1.180	Hazen.
Red Bank, N. J.	Disinfection of Septic Sewage.	.008	.147	.155	PHELPS.
Boston and Baltimore.	Disinfection of Trickling Filter Effluent.	.003	.038	.040	PHELPS.

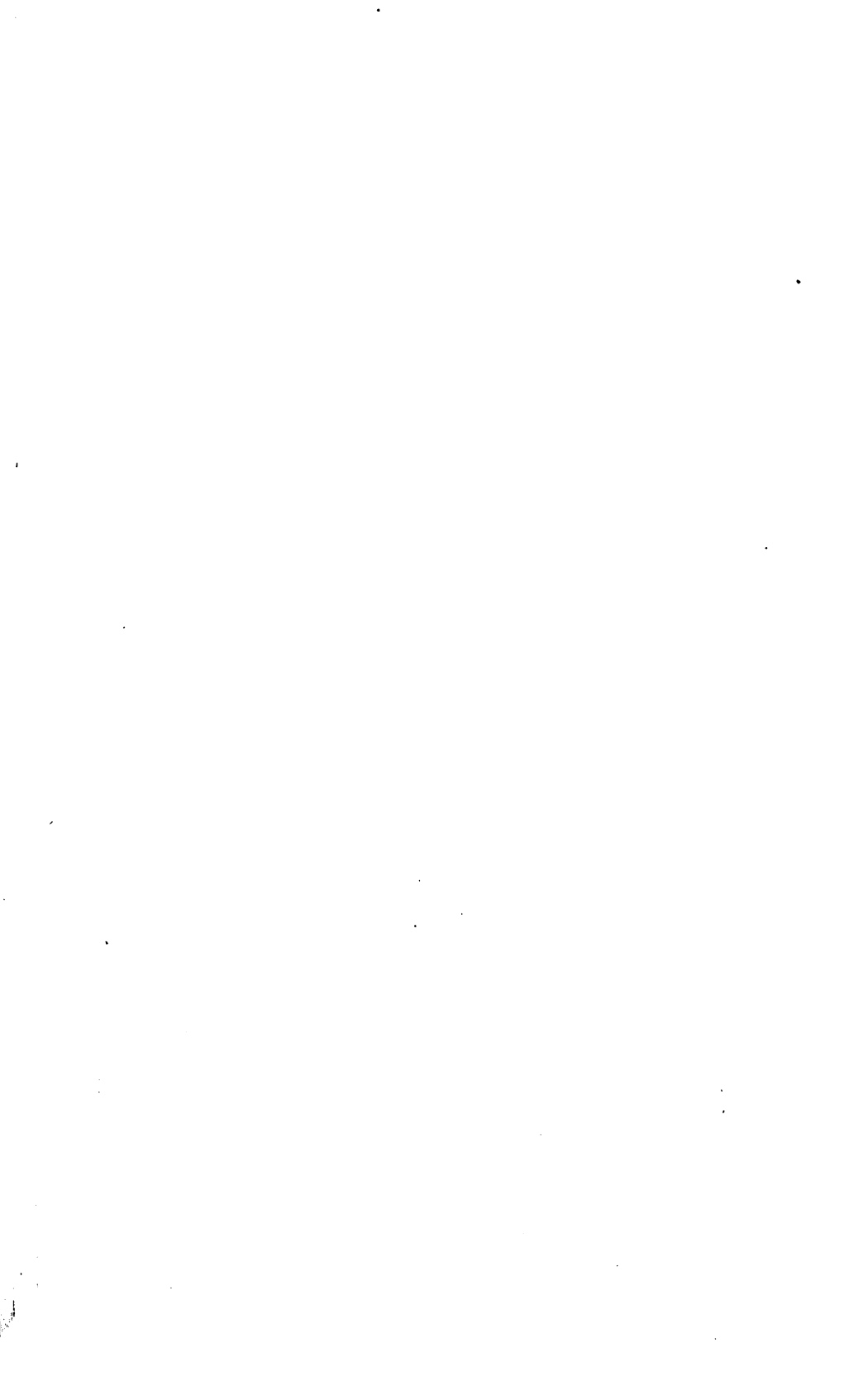
*Average figures based upon total costs and total population of 13 towns.

**Includes capital charges on pumping and new sewers.

NOTES: Screens and detritors tanks are usually included in plants of whatever type and final sedimentation basins are likewise included in trickling filter installations. They are not specifically mentioned in the table.

In cases where plants are known to have been constructed for a greater population than that contributing at present, capital charges are determined upon the maximum capacity, operating charges upon present population.

Interest and depreciation are charged on a uniform basis of 5% per annum. Land and pumping are excluded throughout. In a few cases contributing populations have been estimated from the total flow on a basis of 100 gallons per capita per day.



**THE CHEMICAL DISINFECTION OF WATER AND SEWAGE;
RECENT DEVELOPMENT AND PRESENT STATUS**

By

**EARLE B. PHELPS,
New York City.**

**Reprinted from the Journal of the American Public Health Association,
Vol. I, No. 9, September, 1911.**

THE CHEMICAL DISINFECTION OF WATER AND RECENT DEVELOPMENT AND PRESENT STATUS

EARLE B. PHELPS,
New York City.

Recent developments in the use of chemical disinfectants and sewage purification have been so rapid and so far-reaching in their consequences that there has resulted a somewhat unusual situation. Processes so novel and of such importance that they have been regarded as epoch making have been adopted with a rapidity and to an extent that has probably never been equaled in any other single instance. The total amount of available literature and information upon these processes is probably much less than upon any other important subject that has ever been developed. This condition is primarily due to the unusual simplicity and cheapness of the processes themselves and, secondarily, to the fact that they were first called to the attention of the public at a time when their need was urgently felt. There is a possible question of their general value and usefulness, and the indications are that they are rapidly coming into very general use. The possibility of danger in advancing our practice so far ahead of our past and recorded experience must be obvious. Especially in the hands of the untrained, this apparent simplicity of disinfection methods may be a delusion; and instances are not wanting, even at the present time, when unforeseen and unexpected difficulties have been encountered. At the time seems opportune for a general discussion of the principles underlying the chemical disinfection of both water and sewage, with reference to their scope and limitations in the general scheme of purification methods.

We are further advanced to-day in our knowledge of the principles of chemical disinfection or sterilization than we are in the knowledge of when these processes may be legitimately used. To this latter question the problem therefore attention is particularly directed at this time.

DISINFECTION OF SEWAGE.

The action of disinfectants upon either water or sewage is primarily germicidal one; if at the same time slight chemical changes are produced in the other impurities these are incidental and immaterial factors. The disinfection of sewage is therefore called for only under conditions

* Read at 38th Annual Meeting of American Public Health Association, Milwaukee, [Se

which it is deemed undesirable to allow the discharge of living organisms. Since the pathogenic organisms are the only ones that we may regard as being undesirable, it follows that chemical disinfection of sewage has for its sole purpose the destruction of disease germs. It seems necessary to point out this fact on every possible occasion. The so-called chemical treatment of sewage, or, as it is sometimes described, the chlorine process of sewage purification, seems to have established a name for itself in the lay mind as being a cheap substitute or alternative process for sewage purification of other kinds. It cannot be stated too emphatically that the disinfection of sewage is not a substitute for anything else. None of the other processes of sewage treatment have for their primary object the destruction of germs, unless it be possibly the old slow sand filter. Even if the destruction of germs be the aim in the use of the sand filter that object is rarely attained to any satisfactory degree in practice. No other type of sewage purification can be relied upon to produce bacterial destruction. Effluents from such processes are often no better from a sanitary standpoint, i. e., with reference to the possible presence of disease germs, than the original untreated sewage. It has been the writer's observation that the removal of bacteria observed in various methods of sewage purification is not essentially different from that which is observed in an equal period of time in the stream. Therefore the process of chemical disinfection is unique. It is not a substitute for any other process but a new process with a single and practically unique purpose—the destruction of germs.

Whether or not the destruction of germs is necessary or desirable in any given case is a matter for local consideration. A few of the general principles involved may be laid down without going into any lengthy discussion of the relative merits of sewage purification and water purification in the protection of public water supplies. Surface waters flowing through a populated region require purification to render them safe for domestic purposes, even though they do not receive direct sewage pollution. Furthermore, it is possible to purify badly polluted waters so as to render them fit for domestic use. From these two postulates the position is not infrequently taken, even by some of our eminent state health authorities, that water purification is a sufficient barrier to interpose between the water consumer and a grossly polluted stream, and that efforts toward sewage purification are not only unnecessary but unwise. It would seem, however, that the question might fairly be raised as to how far it is wise to proceed with the unrestricted pollution of streams even though these waters are to be purified before use. It would seem to be almost an axiom of sanitary science that all reasonable precautions against serious

pollution should be taken, and that sources of drinking water supply should be kept as pure as possible, allowing for their reasonable use. Just what constitutes reasonable use of a stream is a matter upon which our courts are still debating. It is of interest at this time to point out that, with progress in sewage disposal methods by which we are able to obtain results of greater and greater excellence at ever-diminishing cost, there will be constantly greater limitations placed upon the reasonable use of a stream. What may be considered an unreasonable demand upon the polluting community today, may, with the improvement in our processes and the decrease in relative costs, be looked upon in the near future as a perfectly reasonable and just requirement. This has been the situation in the sewage disposal problem from the beginning. Only a few years ago, for the authorities to have insisted upon the discharge of disinfected effluents would have been looked upon as an unreasonable and even a ridiculous demand. Today, with the advent of processes of chemical disinfection, such a demand is not only reasonable but is actually being made and enforced in many parts of the country. Thus one role which this process has played in the field of sanitary science has been to make possible through its reasonableness the more perfect purification of polluting waters, thereby diminishing the burden and increasing the margin of safety of water filters and decreasing by just so much the danger of infection.

A second and far-reaching result which has followed the introduction of this process is the protection of the shell-fish industry. Coming, as it did, at a time when this enormously valuable industry was being threatened by the discoveries of bacteriologists and epidemiologists that there was an intimate relation existing between polluted shell-fish and epidemics of typhoid fever, the process of chemical disinfection has been of great value to this industry. The State of New Jersey is today taking active steps toward the full protection of her shell-fish interests by encouraging, as far as practicable, chemical disinfection of all sewage which could by any possibility reach important shell-fish areas. These two applications of chemical disinfection of sewage have been so readily apparent and have had such far-reaching possibilities that the authorities have not been slow in taking them up. Further than this we have not gone at the present time. The danger of pollution along bathing beaches or in waters used for purposes of commerce have heretofore been considered so slight as hardly to justify any vigorous protest. Here again it may be proper to point out that with increasing knowledge of the methods of transmission of disease and with continued improvements in the process of disinfection, the applications of these processes are becoming more and more

general and their compulsory use more and more reasonable. Looking at the matter from another point of view, chemical disinfection has made possible the discharge of disinfected crude sewage under conditions which would otherwise necessitate efficient filtration. Under suitable conditions of volume of diluting water and strength of current there may be no apparent necessity for the thorough purification of sewage. Such favorable conditions are frequently met with along the ocean front and lakes and upon the great rivers. If, under such conditions, bacterial purification is called for by reason of any of the causes previously enumerated, then disinfection of the crude or partially clarified sewage is suggested, and in many cases such methods have been employed. It provides the one definite remedy for the existing ills and accomplishes the desired results at a minimum of cost. The misuse of this simple remedy, however, will prove a disastrous experiment.

These are the things that the chemical disinfection of sewage have accomplished or may be expected to accomplish. It is readily seen that these are not the things that are accomplished by other methods of treatment. On the other hand, the disinfection of sewage is not intended to accomplish the purpose of sewage purification in general. The latter is undertaken for the protection of streams and other bodies of water against possible nuisances of the grosser sort or against physical nuisances which follow the discharge of untreated sewage into a stream which is too small to give the proper dilution. Where nuisances of these kinds occur the benefits of chemical disinfection applied to relieve putrefactive conditions or for the destruction of germs which are primarily responsible for this condition, are temporary at best, and in the long run futile. Any attempt to oxidize organic matter and in this way rob the sewage of its putrescible characteristics will also at the present time prove futile by reason of the cost involved. There is a possibility that some cheap chemical method of oxidizing organic matter may eventually be discovered. If ozone could be produced today with any approximation to theoretical efficiency it could undoubtedly be employed for that purpose; its vigorous oxidizing action makes it an ideal reagent. But under the present methods of manufacture, giving as they do only five or six per cent. of the theoretical yield, the cost of ozone makes its use in sewage disposal, even as a germicide, prohibitive.

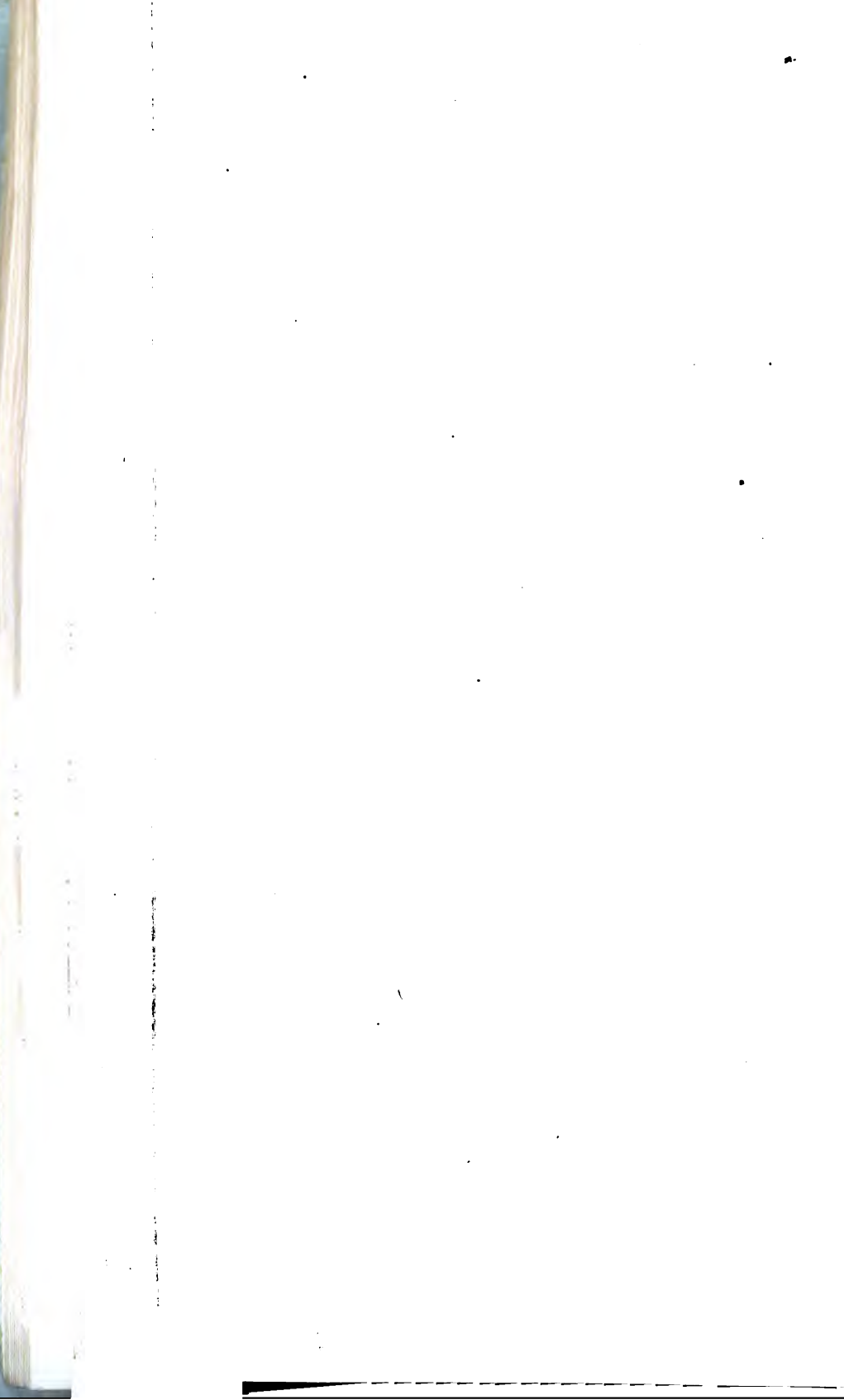
DISINFECTION OF WATER.

In the field of water purification disinfection by chemical means bids fair to revolutionize our practice; but here again, as in the case we have just considered, careful attention must be paid to the limitations of this

process and the field which it is designed to cover; chemical of water is only incidentally and partially a substitute for other. It happens that in water purification the removal of germs is the primary object. In addition to this object, however, and exceeding it in actual importance, is the removal of other impurities either mineral or organic origin, color, suspended matter such as clay, or, in certain waters, finely divided material discharged from factories. These are typical examples of the kinds of impurity which it may be necessary to remove. In the absence of impurities of these various types, in cases where minor sources of continuing bacterial pollutions exist, or in the further case of a temporary but more serious bacterial contamination, the application of chemical disinfection is fully justified. The character of the untreated waters is such that, regardless of how the use is repugnant to the physical senses, then more far-reaching than that obtained by mere disinfection, is assuredly indicated. As an adjunct in water purification, disinfection has a much more important field. Particularly in connection with the mechanical filtration process, will this process be found valuable. Rates of flow upon slow filtration are determined primarily by the physical character of the water and the effect of the contained impurities upon the expensive process. On the other hand, rates of treatment on mechanical filters are determined largely by the necessity for bacterial efficiency. Therefore, in the case of certain special types of water the aid of chemical disinfection may make higher rates of treatment upon slow filtration possible, this supplementary process will undoubtedly find a wide development in the field of mechanical filtration.

Another possible field for chemical disinfection, which has not attracted the attention which it deserves, is its emergency use in case of some mishap by which the water system suddenly becomes contaminated. It should be the duty of every water-works manager to provide, at a slight expense, the necessary storage tanks and chemicals which will enable him at a moment's notice to disinfect his entire supply. If these were never used such a plant would represent a very cheap form of insurance against possible accident and loss of life.





Reprinted from Journal of the New England Water Works
Association, Vol. XXV, No. 4.

Copyright, 1911,
By the New England Water Works Association.

HAS THE TIME COME FOR DOUBLE MU-
NICIPAL WATER SUPPLIES, ONE — NAT-
URALLY PURE — FOR DRINKING AND
COOKING, THE OTHER — DENATURIZED
OR STERILIZED — FOR ALL OTHER PUR-
POSES?

— BY —

W. T. SEDGWICK AND H. P. LETTON.

(From the Sanitary Research Laboratories of the Depart-
ment of Biology and Public Health, Massachusetts
Institute of Technology, Boston.)

HAS THE TIME COME FOR DOUBLE MUNICIPAL
SUPPLIES, ONE — NATURALLY PURE — FOR
DRINKING AND COOKING, THE OTHER — DENATUR-
ED AND STERILIZED — FOR ALL OTHER PURPOSES?

BY W. T. SEDGWICK AND H. P. LETTON.

(From the Sanitary Research Laboratories of the Department of Biology and Chemistry,
Massachusetts Institute of Technology, Boston.)

[Read November 8, 1911.]

It has often been proposed that two water supplies be provided for cities, one to furnish water of the highest quality for drinking and cooking, and another for all other purposes. The advantages of this plan were recognized as far back as the time of the Roman Emperor Frontinus,¹ writing in A.D. 97 concerning the water supply of Rome, states that the water from one aqueduct was reserved exclusively for drinking and cooking purposes, that from another was reserved for baths, and that from others only for irrigation. In modern times the question has also been seriously considered by Brackett² having made a report to the Metropolitan Water Board in 1895 on a separate supply for the city of Boston. The question has also been discussed in a more general way by Axtell,³ and others.

Our large cities with but few exceptions obtain their water supply from rivers, lakes, or large artificial storage reservoirs. These sources are in some cases grossly polluted, and many which are not polluted at present are in constant danger of becoming so notwithstanding the fact that elaborate precautions are taken to guard against contamination. In case the present source becomes polluted, the city will generally be compelled, sooner or later, to the expense of constructing a filtration system or of obtaining a new supply from a more distant, non-polluted source. It is having as a source of supply lakes or artificial reservoirs which require maintain a constant and efficient oversight of the water supply in order to guard against pollution. Moreover, no matter how complete and efficient the system of filtration or the supervision

watershed, these provisions are not always infallible as safeguards. This is shown by the typhoid fever epidemics at Lawrence, Mass., and elsewhere, due to trouble with the filters, and those at New Haven, Conn.; Scranton, Pa.; Plymouth, Pa.; and many other places, due to pollution of the watersheds feeding the storage reservoirs.

We are at present in a peculiar position — namely, when most of the water supplied to our modern communities is not used either for drinking or for cooking, and yet, since any of it may at any time be used for these purposes, all of the huge streams that pour through our cities are expected to be, from the sanitary standpoint, above suspicion. Thus far we have got on fairly well under this arrangement, but the time will probably come when the amounts so required will become so vast, and so costly to keep up to the required purity, that we shall be driven to double supplies, one for drinking and cooking, the other for all other purposes.

Even if it be granted, however, that with proper precautions the danger to the public health from ordinary water supplies is small, the question still deserves to be considered whether from a sentimental or esthetic standpoint the time has not come for double municipal supplies.

For it is an open secret that many persons dwelling in cities provided with filtered water supplies derived from polluted sources cheerfully purchase spring or other waters which they believe to be naturally pure rather than drink the purified waters which are known to come from sewage-laden sources. It must be admitted, moreover, that it is by no means agreeable to dwell in detail upon the proximate sources of some of our most reputable water supplies, derived as these often are more or less directly from streams laden with human excrements or with street washings, the drainage of slaughter houses, of hospitals, and the like. Some years ago we were grateful for even a moderate degree of cleanness, but our standards in these matters are constantly rising, and decency is everywhere more and more being added to health as a consideration of importance in public affairs. Again, many filtered waters are at times colored or turbid, or have a disagreeable taste or odor, due to the presence of organic matter not removed by the filters, although the bacterial efficiency of the latter may be high. Water

obtained from impounding reservoirs is also often colored marked taste or odor, due to the growth of microscopic organisms. The New York and the Boston supplies are examples of this. In order to prevent such growths the reservoir is sometimes in construction, at great expense, completely stripped of its layer of soil; and even then the result may be only partially successful. Again, a water from a surface supply is frequently warm during the summer months and correspondingly less palatable than a ground water with a fairly constant temperature year round.

The average daily per capita consumption of water in the United States, with a population of 100 000 or more, is 115 gallons, and of this amount Brackett ⁵ has shown that only 35 gallons are used for domestic purposes, while the amount actually used for drinking and culinary purposes is less than 10 gallons. If, however, we allow 10 gallons per capita per day and consider the fact that this would only be 100 000 gallons per day for a city of 100 000 population, we are once more convinced that it would be possible in practically every city to obtain a sufficient supply of ground water that would be cleaner and more potable than most surface waters, even if they are filtered.

We are in the midst of a mighty sanitary awakening, spending millions of dollars every year in protecting and purifying our water supplies, yet of all the water distributed probably less than three per cent. actually concerns the public health. In this fact in mind it is evident that we seem to be following an economical course, and that any plan for betterment of our water supply should be thoroughly investigated.

Heretofore, whenever the question of a double supply of water was proposed, the one insurmountable objection has been that it would be impossible to prevent people from drinking from the surface or impure supply. This was clearly shown at Lawrence, Mass., in 1893. The city used a filtered supply from the Merrimack River, while in some of the mills the raw river water which was polluted with sewage was used for washing. During the summer there were nine deaths from typhoid fever of mill operatives who had drunk the river water notwithstanding the fact that they

fully warned of the danger, while the total number of deaths from typhoid in the entire city was only seventeen.

In order to make the double system practicable it is necessary (1) *to so regulate the use of the smaller supply that it shall not be wasted*, and (2) *to so treat the larger supply that it shall not under any circumstances be used for drinking*.

The first condition could be attained by making the cost of the water such that its value would be appreciated, and by metering all services. It is the second condition, or that of *denaturizing* or *sterilizing* the supply, so to speak, that is the main object of consideration in the present paper.

In recent years there has come into general use an agent which it is believed will be a satisfactory *denaturizer*, both from a sanitary and an economic standpoint. This substance is calcium hypochlorite [$\text{Ca}(\text{OCl})_2$], which is being extensively employed as a sterilizer for water and sewage. Its especial fitness for the case under discussion lies in the fact that if put into a water in such quantity that it is not all decomposed, it imparts to the water an odor and a taste that are very disagreeable. With a water thus treated its use for drinking would be very rare, and even if it were so used no harmful results would follow, as the water would be practically sterile and as a little undecomposed hypochlorite is probably not detrimental to health. Brackett has shown⁵ that about ninety per cent. of the water used for domestic purposes is employed in flushing water-closets, in wash tubs, in bath tubs, and in sinks and bowls. The addition of the hypochlorite would not affect the use of the water for any of the above purposes if we except the small amount used for drinking and cooking. From the same authority it appears that of the water used for commercial purposes the larger portion is employed in steam railroads, factories, elevators, power plants, and office buildings. The hypochlorite would affect the use of the water in very few, if any, of the above cases. It is also quite evident that it would not affect the public use of the water for such purposes as street sprinkling, ornamental fountains, sewer flushing, and fires, but would instead be a benefit on account of its disinfecting action.

From a consideration of all the above facts, it appears that as a sanitary measure the plan is highly commendable. To determine

whether it is economically practicable is a much harder problem, as this will be established largely by local conditions. It would, of course, be necessary to install a separate distribution system, although this would be of much smaller piping than the existing one, it would still be the large item of expense. Separate valves and meters would also be required, which would be another item. These, however, are points which would have to be considered as special problems in each individual case.

The object of this paper is merely to present the problem stands to-day to water-works officials, engineers, and sanitarians in the belief that it is a new aspect of an old problem, and that it can be, and will be, profitably applied in some cases in the future.

REFERENCES.

- ¹ Herschel. Frontinus and the Water Supply of the City of Rome, p. 65.
- ² Brackett. Water Supply of Different Qualities for Different Purposes. Report of the Massachusetts State Board of Health on Metropolitan Water Supply, 1895, p. 217.
- ³ Axtell. Pure Water for Drinking and Cooking. *Eng. Mag.*, 1896, xi, p. 67.
- ⁴ McElroy. City Water Supplies of the Future. *Eng. Mag.*, 1894, vi, p. 821.
- ⁵ Brackett. Consumption and Waste of Water. *Am. Soc. C. E.*, 1895, xxxiv, p. 1.

DISCUSSION.

MR. CHARLES W. SHERMAN. The paper certainly presents a very interesting possibility, and there can be no question from an engineering point of view that it would be practicable. The question, as it occurs to me, is the economic one, which the authors have already called attention to. It would undoubtedly mean an expensive water supply to furnish a double supply in this way. It is perfectly conceivable that there may be cases where that expense would be warranted.

THE PRESIDENT. Will Mr. Weston say something about the probable effect of an excess of chlorine on the pipes and water-works fixtures?

MR. ROBERT S. WESTON. Mr. President, I was just about to ask the author of the paper that question. I wondered whether it would not be an objection. I should think the addition of chlorine would make the water more corrosive than it was before; whether it would be appreciably more so or not, I could not say.

MR. ARTHUR N. FRENCH. You may be interested to know

we are using chloride of lime (about six pounds per million gallons) at Hyde Park. I do not know that there is any other place in Massachusetts that is doing it. We have been using it for about a year, and I cannot see that there is any effect upon the water that is disagreeable. People drink it and do not make any objection to it. Our water is well water, and it is fairly clear and does not carry very much sediment. We began to use it because we had a typhoid-fever scare last year, there were several deaths, and we started the use of it as a matter of safety. The State Board of Health have knowledge of it, and have been out to investigate it, but they have neither approved nor disapproved. I cannot see that it corrodes the pipes any more than the plain water did. It corrodes the implements that we use in mixing up the solution very badly. Wooden pails will last only a very short time, and galvanized iron is eaten out fairly quick. Our plant is only a temporary one, for we expect to take the Metropolitan water now in a short time, so that we have not put in anything permanent.

THE PRESIDENT. If you will try using sixteen pounds for a day or two instead of six, you may get some new light on the smell question.

MR. FRENCH. Of course that would make a difference.

PROF. E. B. PHELPS. Mr. Sherman's remarks as to the expensiveness of this plan seem to me not to be of general application. One can easily conceive a situation in which a town is face to face with the proposition of going quite a distance and at considerable expense for a new supply of sufficient magnitude and proper quality for all purposes. Now if there be near at hand a supply of ample magnitude, although of inferior quality, it might not be necessary to go so far afield for the small pure supply, and it seems to me in such a case this plan might easily work out a real economy.

In regard to the question of corrosive action, I can state that I have had under my personal observation three installations in which water is pumped which has been previously treated with hypochlorite. I have had special notice taken of the interiors of the pumps from time to time and there has been thus far not the slightest sign of any injurious action. One of these plants has been in operation for about ten months and the water is receiving

hypochlorite in the proportion of about $7\frac{1}{2}$ lb. per million and the others have been in operation for eleven months and two years respectively, the hypochlorite averaging about 10 and running as high as 12 on occasions. Furthermore, in these cases, nor of several others which I have had under immediate observation for some time, have there been any complaints from or indications of corrosion in the pipes. A study of the chemical principles involved has led me to think that the action of this extremely dilute and slightly alkaline solution is protective rather than otherwise, a conclusion which I think is amply justified in the results. In a concentrated solution, which the solution itself is handled it is quite true that the protection due to the alkalinity is more than offset by the corrosive properties of the free hypochlorous acid liberated.

MR. RANDOLPH BAINBRIDGE. I might say that in Quincy at the present time the Fore River Shipbuilding Company uses about half a million gallons of water a day, and has found it expensive to buy Metropolitan water, has therefore supplied with a reservoir of its own. All fixtures therewith are labeled "Industrial Water." As far as I can find out from observation, from what my men tell me, and what the men at the plant say, there is absolutely no harm whatever with anybody using the wrong water.

In this connection I might say that this water is not used in any way whatever. It is simply that the water from the reservoir, which is, as has been described, street water, water from fields and barnyards, and so on, is used for industrial purposes, the Metropolitan supply is considered good enough for anybody to drink. Last winter the company wanted to enlarge the plant to about a million gallons a day, and the old Quincy reservoir, and in fact entered into a contract with the city to do so. We found, after we had made a contract with the state would want the city to pay them three times what they could get from the company. In other words, we have a supply that is good for a million or a million and a half a day, and would answer the very purpose we have been speaking of, a secondary supply, but we have to pay the state for the privilege of using it about twice what we can get for the water

But there is no question whatever but what this thing is coming. The farmer, the granite man, and the manufacturer at the present time do not get a square show at the water. What you have to charge in any water-works system, whether 20 cents or 15 cents or 10 cents a thousand gallons, is practically robbing the manufacturer, and I do not suppose that this shows up in any other city plainer than it does in Quincy. Lots of our people use well water for boilers, but that makes work for the boiler men. As has been said, about 5 gal. a day of pure water is enough for practically all that a secondary supply would be needed for, and large local supplies would thus be available for industrial purposes.

MR. FRANK C. KIMBALL. That the time is coming when some conservation of potable water will have to be made, I think is beyond question. Whether a double supply can be put in at an expense which will pay from the present standpoint of proper charges for water is a question. If, as Mr. Bainbridge has suggested, a charge of ten cents a thousand gallons is too high for water for such uses as he mentions I doubt if the time will come very soon when even industrial water can be treated in such manner that it cannot be used for domestic purposes, and at the same time not so radically treated that it will not be offensive for other purposes, at much less price than that, separate distribution and pumping also being considered. I am speaking now, of course, of municipal supplies as a whole. This is a subject, however, that I think it is very pertinent for an association like this to consider, and sooner or later the problem of a double supply of water will have to be worked out for some communities, although it will probably be a long time before it is necessary for the majority of them to take up this question.

MR. JOHN H. COOK. Mr. President, this matter is, like the tariff, a local question. There may be times when it will pay, and there will be other times when it will not pay. It seems to me every situation would have to be judged by itself. So far as treating the water successfully without making it offensive goes, I think that it generally can be done without trouble. We have treated some 40 million gallons a day for the people of Jersey City, as is doubtless well known to many gentlemen here, for some time, and without any complaints whatever from the people who have used

the water. The treatment is extremely inexpensive, and I suppose that with most waters it would be perfectly satisfactory except to a man who knew it and did not like the idea of it. The idea is that it will be a long time before a double supply is introduced in our communities. We have a great many communities that are supplied, or were supplied formerly, with two separate systems, one system for toilet purposes and another for drinking, and this was never a very successful proposition. The employees who got on drinking the wrong water, although the taps were always marked with brass tags which said, "Do not drink this water," or "This water for drinking purposes." The help would drink instead of the water and we did not find it at all successful.

MR. SHERMAN. Mr. Phelps's question suggests that I might amplify my previous remarks a little, with regard to the expense of the proposition, and bring out more clearly the points which I especially had in mind. I do not doubt that a separate distribution system and the supply works could be put in in many cases at a cost which might be feasible; but when it comes to the duplication of the plumbing, I think the householder would not take it very seriously, unless it was in the comparatively rare cases where he is willing to pay twenty dollars or thirty dollars for hot spring water in addition to the ordinary house supply. I think it is likely that he might be willing to stand the double expense.

THE PRESIDENT. I think the double plumbing is a very important question. I would like to know what the plumbing costs as compared with the water supply. It is my impression that in Boston the plumbing costs more than the Metropolitan Water Works. Does anybody know about that?

MR. GEORGE A. CALDWELL. The cost of the plumbing for a separate supply for drinking purposes only would not be a very important matter. For an ordinary twelve-room house with, say, four outlets for drinking water only, the cost of the extra piping and brass pipe, not including the meter or the service from the street to the house, would not exceed \$50, including all labor and material for the work. In many cases the cost would not exceed \$25, and I believe the average cost based on a twelve-room house with four outlets would be about \$35.

MR. JOHN C. CHASE. It strikes me that the installing of two separate sources of supply in an ordinary community would be a very serious proposition to consider. I can see only one way in which it would be practicable, and that is that the residence portion should be supplied with pure water, and the business and manufacturing sections with the second quality for commercial purposes so arranged that none of it could be used for drinking purposes. Moreover, the ordinary dwelling house would not use such a great amount that it would be necessary to supply it with a secondary supply; and in the manufacturing sections, I think it would not be a very difficult matter to arrange for the use of a water that is not up to the required standard for domestic uses, segregating it to such an extent that there would be no danger of using it for drinking purposes.

I have in mind a case in Haverhill, Mass., where typhoid fever appeared in one of the factories a few years ago, and, if I remember right, it was found that the help instead of using the city water were drinking from a nearby faucet which was supplied with impure river water. I think it would be utterly impracticable to put two kinds of water into a place where there is a chance of the undesirable one being used. My experience with the average workman is that he will take what is handiest.

THE PRESIDENT. I remember that this system was used some years ago, though perhaps not fully, at Augusta, Me., when the main supply at that time was taken from the Kennebec River, and a spring-water supply was piped throughout the city and into nearly all residences, and was sold separately. This was known as the "Devine Spring Water." I was much interested in that when I first heard of it, but I found that the name came simply from a Frenchman on whose farm the spring was located. Afterward Augusta secured a new supply of excellent quality and the Devine spring fell into disrepute.

PROFESSOR SEDGWICK. *Mr. President and friends*, — I want to begin by saying how glad I am to be here again and to see the faces of so many old friends, and of those who would, I am sure, be new friends if I were fortunate enough to be able to attend more of your meetings. It has been a real regret to me that for the last few years I have been able to be present so seldom. But I am sure

since I see so many of the old officers are still on deck, and of the old members still present, that the Association keeps its old traditions. And it was with that feeling that Mr. Letton and I brought this paper here to-day.

In a discussion before one of our classes, last year, on the use of calcium hypochlorite for the treatment of water to which this material is already being put for one purpose or another, Mr. Letton used the happy term *denaturizing* whereupon I asked him to work up this subject of a double supply and bring it up to date. I remembered Mr. Brackett's remarks and I have long been impressed, as, of course, everybody has, by the fact that while most of the water that we have in our cities is not used for drinking or cooking, all of it has to be fit to be used for cooking, — a condition which is certainly anomalous, and in certain cases and under certain conditions leads us to wonder whether we cannot do something about it.

There is another side of the subject which appeals to me much as a sanitarian, and has long done so, and that is the sentimental objection to a water which is half as good as filtered dilute sewage. Now, I would not for a moment go back on filtration; let that be distinctly understood. The introduction of filtration has been one of the greatest blessings that ever befell the community or the water-works profession. At the same time, there is no doubt that it is not a pleasant thing to have to drink down and reflect, if one must do so, that the particular water which comes to his table, or into his kitchen, and is used for cooking and drinking, is separated from dilute sewage, and that you can see fecal matters, by a little layer of sand only a few inches thick. The origin of drinking water is important, and is well recognized by all filtration men. The purer the raw water, the higher the grade of it, the better. There are communities where I could name some of them, where the water supply is obtained more, from one point of view and stating it in its worst form, from filtered dilute sewage. And it is a great comfort to know that we can filter a highly sewage-polluted stream in such a way as to make it powerless to injure the public health. At the same time, it is not always a pleasant thing to stop and wonder what went into the water just before it was filtered, or what

it at the time. There are communities that would gladly pay a good deal if they could get a pure upland water rather than have filtered water derived from a source of the sort to which they must now go.

With those thoughts in mind, and recognizing, as I must as a sanitarian, the fact that our standards are constantly rising, and that decency is everywhere to-day being linked up with hygiene and sanitation, original cleanliness getting an increased value all the time, it seemed to me worth while for Mr. Letton to work out this matter, and I took up the subject afterwards with him with a good deal of interest.

Now, to begin with, when we have two kinds of public water supply, one of which is good and one of which is bad, there is absolutely no insurance against the use of the bad supply by careless people. That idea has been emphasized sufficiently already, and it is a well-known fact that there are plenty of people in a community who, if a water looks fairly well and tastes fairly well, will drink it even if there is a sign right over the tap from which they draw it saying that the water is not fit to drink. I remember seeing that illustrated in Lowell and in Lawrence, and I remember seeing it in Italy, where they had the same sign (*aqua non potabile*) over some of their waters that are not supposed to be used for drinking. Of course you may say that that is of no consequence except to the man who disobeys the rule; but it is of great consequence to the community, because every case of typhoid fever or other infectious disease arising in a community, even in a person of no particular consequence *per se*, is of great importance, or may be of great importance, to the community. Every such case is a nest or a focus of disease from which disease may spread. If, for example, it is a careless workman who comes down himself with typhoid fever, you may say, "Well, he is simply paying the penalty for his carelessness." But if that man has typhoid fever in his home, and his sister, or his sister's daughter, or his own daughter, happens to be a servant in your kitchen or mine, or in your nursery, and brings the germs of the disease to your house or to mine, it then becomes a matter of serious importance to the whole community. "We are all members one of another" nowadays even more than in ancient days, and getting more and more so as

population thickens. So that, even in the case supposed, not merely the penalty the man pays who drinks the water, but it may be the penalty which the community pays for having bad water accessible for drinking.

This has been and always will be the objection to two supplies, one good and one bad and infected with the germs of disease. But this plan of denaturizing the water removes that objection. The proposition is simply to treat the inferior water in such a way that if it should be used for drinking, for which it is not intended to be used, no harm will result, unless it be a bad taste in the water, possibly, if the denaturization is strong enough for that. At the same rate, the water by the denaturizing agent used will itself be practically sterile. And in that connection I may say that it is not necessary to so overload the water with the hypochlorite that it shall have a bad odor or taste, although on some occasions it would be well to do that. It is sufficient if enough be used to sterilize the water, and that can be done judiciously, as is shown in many communities, without producing a bad taste or smell. It is not, then, a question between a bad smelling water and a bad tasting water and a good water; it is a question between two kinds of safe water, one derived from sources naturally pure and the other above objection on the score of sewage origin; the one standing in that category, but coming from objectionable sources.

The whole object of the paper, however, is merely to emphasize the fact that we now have in our possession a material which we can, if we want to, denaturize any water, and more to show that this method has been used in emergencies. When, for example, a typhoid fever epidemic has broken out, as in Torrington, lately, and it was necessary to do something immediately for the water, a quick disinfecting plant with this same hypochlorite introduced, as has been done in several similar instances, and the water going to everybody has been denaturized for a short time. In the state of Kansas I noticed the other day, in the report of the State Board of Health, they keep, so to speak, a "wrecking crew" ready; that is to say, they keep an emergency hypochlorite plant on wheels ready to run off to any town in the state that has a typhoid-fever epidemic due to the pollution of its water supply. It would be a good plan in any state where the water supply is

seriously open to suspicion. It is, in fact, done in more places, I fancy, than is commonly reported. The wise State Board of Health will everywhere have in its engineering department, if it suspects the likelihood of any such need, some such plant always ready for emergencies. This, as I have said, was the main point, to bring the matter up here for discussion.

On the economical side, we realize, of course, that cities that are already provided with good water supplies would never think of embarking on this scheme; neither would those cities which can get abundant water think of doing anything of the kind. It will only be in some special, peculiar situations, where water from a good source cannot be obtained in sufficient quantity, except at an almost prohibitive expense, or where for some local or peculiar reasons it may be desirable to have two systems of supply. But it seemed to me, and I think the discussion has justified the belief, that an Association like this, that is always anxious to know whatever good is going on, and whatever is possible under new or trying conditions, might take this up and discuss it with advantage; and I am sure that both Mr. Letton and I are well satisfied with the discussion that has taken place. It has brought out exactly the objections which might have been anticipated, and a rather surprising amount of concurrence with our general contention, which is simply this: That we have here a new agent, useful under certain circumstances, the whole thing being, as Mr. Letton said, simply a new aspect of an old problem.



THE APPLICATION OF CERTAIN LAWS OF PHYSICAL CHEMISTRY IN THE STANDARDIZATION OF DISINFECTANTS.*

EARLE B. PHELPS.

(From the Biological Laboratories of the Massachusetts Institute of Technology.)

The idea of standardizing disinfectants was first seriously proposed by Rideal and Walker.¹ Previous to that time, despite the fact that the germicidal properties of a great many chemical substances had been thoroughly investigated, no scientific attempt had ever been made to establish a common basis of comparison. The results of any disinfection experiments are fundamentally influenced by such conditions as temperature, character of the organism employed, number of organisms in unit volume, and character of the medium. In the absence of complete data covering these points results are practically worthless, at least for purposes of comparison. Even with such data given it is still impossible, owing to the variable conditions obtaining in practice, to establish any relationship, or order of excellence, among the various disinfectants. At best we can only hope to establish such relationship under specified experimental conditions. Rideal and Walker proposed to establish phenol as a standard. This selection was made because phenol is a substance readily obtainable anywhere in a comparatively pure condition. The effect of phenol and that of any other disinfectant may be determined simultaneously using the same test organism. The germicidal power of the disinfectant under investigation is then expressed as the "carbolic-acid coefficient," this being the ratio of the concentrations of the two disinfectants which will kill all the test organisms in the same time. Rideal and Walker recognized also that the time required to disinfect was dependent upon the number of organisms initially present as well as upon the temperature, a fact previously pointed out by Krönig and Paul.² These variable factors were controlled as closely

* Received for publication July 18, 1910.

¹ *Jour. Roy. San. Inst.*, 1903, 24, p. 424.

² *Ztschr. f. Hyg.*, 1897, 25, p. 1.

as possible. To these possible variables, which it has been necessary for the present to fix arbitrarily, Chick¹ has added a third, namely, the time element. Instead of noting the time required for disinfection with varying concentrations of the disinfectant she determines the concentration necessary to disinfect in a given time. She selects 30 minutes arbitrarily. In discussing the time element it is pointed out that in comparing the action of phenol and mercuric chloride upon *B. paratyphosus* at 20° C., the concentrations necessary to kill in 2.5 minutes have a ratio of 1:5, while those necessary to kill in 30 minutes have a ratio of 5:1. The selection of a constant time factor is therefore necessary if a constant carbolic acid coefficient is to be obtained. A coefficient thus obtained is truly indicative of the relative value of the disinfectant in question only at the concentration at which the test was made. At any other concentration a new coefficient would be obtained.

Chick therefore establishes three arbitrary conditions of experiment for the comparison of disinfectants. The temperature must be standard, preferably 20° C.; the initial number of bacteria must be the same in each comparison; and the time required to complete the disinfection must be fixed at 30 minutes, or some other constant value.

In thus fixing the variables entering the problem it is indeed possible to determine relative values or carbolic acid coefficients under the restricted conditions of the comparison. But are not these variables precisely the ones which are not fixed in practice? Given the relative values of two disinfectants at 20° C., what relation exists at 0° or at 40°? Mercuric chloride will destroy germs in two minutes at a concentration of only two one-thousandths of that required by phenol for the same result. If results are desired in two or three minutes, however, the concentration must be about one-tenth of that of phenol. We may want a comparison under these conditions or under longer periods of time, four or twenty-four hours. In brief, by the establishment of arbitrary fixed conditions in our comparisons we deprive the results of their practical value. Such a course might still be permissible if the work

¹ *Jour. Hyg.*, 1908, 8, p. 92; also Chick and Martin, *ibid.*, p. 654.

involved in determining the complete relationships were very arduous or if the mathematical expression of these relationships were unwieldy or unusable. Such, however, is not the case. Not one constant, but three, one for each variable condition met with, are necessary to completely describe a disinfectant with reference to phenol and to one type of bacterium. This latter is the only variable entering the practical problem which must be arbitrarily fixed in the experiment. It seems at present to be quite necessary to determine the relative germicidal values of two disinfectants upon the actual kind of germ upon which they are to be employed and to qualify the final comparative results accordingly.

With this one fixed factor, however, and by the aid of certain simple principles of physical chemistry, it is possible to derive mathematical expressions involving all the other variables in the complete problem. These expressions are convenient to use and may be put in such form that the actual labor of making the tests is reduced to a minimum. A brief discussion of the principles involved will be necessary to their clear understanding. Unfortunately the calculus must be resorted to, but when possible the actual meaning of the differential expression is stated.

The particular law of physical chemistry which will be considered first is known as the law of velocity of reaction. It may be briefly stated as follows:

In any chemical reaction the amount of change in the reacting substances in unit time is directly proportional to some power of the concentrations of those substances. Just what factors determine the power in question need not be considered at present. It is sufficient to state that, in what are known as monomolecular reactions, it is the first power that is involved so that, in these cases, it may be stated that the velocity of the reaction or the amount of change in unit time is directly proportional to the concentration of the reacting substance.

It has been shown furthermore, by Madsen and Nyman,¹ and more conclusively by Chick, that the killing of bacteria by disinfectants simulates a monomolecular reaction in which the bacteria take the place of one of the reacting substances. The other reagent,

¹ *Ztschr. f. Hyg.*, 1907, 57, p. 388.

the disinfectant, is present in such excess that its concentration is not materially altered during the process. The effect of varying concentrations of the disinfectant will be discussed separately. For the present also the temperature will be considered constant. Under the assumed conditions, if b represent the number of bacteria present in unit volume after any time, t , has elapsed, we have the differential expression,

$$-\frac{db}{dt} = kb$$

where k is known as the velocity constant. This is merely a mathematical expression of the law cited above, and means that the change in the number of bacteria per unit time is proportional to the number present. To determine the total change in an elapsed time this is integrated to

$$\log \frac{B}{b} = kt$$

in which B is the number of bacteria initially present. The test of the applicability of this formula is the constancy of k under constant temperature conditions but with varying values of t , B , and b . The experiments previously cited have shown that k varies with the kind and concentration of the disinfectant, with the temperature, and with the bacterial species, but otherwise it is constant in each experiment. In other words, this constant is a definite measure of the value of the disinfectant. It indicates the rate of disinfection. The larger the value of k the more rapid the disinfection and the more efficient the disinfectant. It may be compared directly with the similar constant obtained with phenol. It will be noted particularly that k is independent of the initial number of bacteria present and furthermore that it does not involve complete disinfection. The point of practically complete disinfection is indefinite and its determination involves large percentage error. With such a formula as that given above, a point of 50 per cent reduction would serve the purpose much better, and a degree of accuracy is secured with a small number of tests which would necessitate many times that number under the other method.

The effect of varying the concentration of disinfectant must next be considered. Returning to the original equation and includ-

ing now the concentration of the disinfectant as well as of the bacteria, we obtain

$$-\frac{db}{dt} = KbC^n$$

in which C is the concentration of the disinfectant expressed in any convenient form, and n , an exponent indicating the order of the reaction. As previously pointed out, in a monomolecular reaction, n is unity, but for the disinfectant, n may have another value and must be considered. This constant, n , expresses mathematically what Chick has pointed out experimentally, that mercuric chloride may have a "carbolic-acid coefficient," of 13 at one concentration and 550 at another. If, therefore, n can be determined, it will be unnecessary to adopt a standard time of testing, and the properties of the disinfectant will be more fully determined. Integrating again

$$\log \frac{B}{b} = KC^n t$$

Hence, KC^n is the k of the previous expression. It varies with the concentration and may be determined as already indicated for two concentrations of disinfectants. Let the values be k and k' , C and C' respectively. Then

$$n = \log \frac{k'}{k} \div \log \frac{C'}{C}$$

Having C and n , then it is possible to calculate K . This is the true velocity constant of the disinfectant, being independent of the concentration, and thus differing from k which is constant only at constant concentrations. The constant, n , may be called the concentration exponent. It defines the relative strengths of two different concentrations of the same disinfectant. The two constants, K and n , therefore describe the fundamental characteristics of a disinfectant at any given temperature. Before discussing them in detail, the relation of temperature may be considered. A second law of physical chemistry has been empirically established as follows:

As the temperature increases in arithmetical progression the

* Common logs may be used.

velocity of reaction increases in geometrical progression; or mathematically expressed

$$\frac{K'}{K} = \theta^{(T'-T)}$$

in which K' and K are the constants of the reaction at the temperatures T' and T respectively and θ is the temperature coefficient. It has been found in the case of most chemical reactions that the velocity increases from two to threefold for each rise of 10° . Among the bacterial reactions, however, the increase is greater, varying, according to Chick, from two to fourfold in the case of metallic salts, to seven or eightfold for phenol and similar compounds. A third constant, the temperature coefficient, is therefore necessary to express this characteristic of a disinfectant. The agreement of the disinfecting reactions with the temperature law of chemical reactions has been satisfactorily demonstrated in many instances and may safely be assumed in all cases. Comparisons made at two temperatures 10° apart furnish a basis for the calculation of the temperature coefficient. With this coefficient determined, the value of the velocity constant at any temperature may be calculated from the following:

$$K_{T'} = K_{20^\circ} \times \theta^{(T'-20)}$$

These three constants, the velocity constant, the concentration exponent, and the temperature coefficient, define three essential characteristics of the disinfectant. The last two are independent of experimental conditions. The first, however, is determined also by the type of test organism employed. Therefore any standardization of a disinfectant must be referred to a particular organism. To further correct the result for the uncertain resistance of the particular culture used, the value of K may be divided by the value similarly obtained for phenol. This gives a coefficient independent of all variables except the nature of the test organism. If the temperature were not 20° , reduction can be made by the formula above.

The minimum amount of work required to determine the three constants of a disinfectant is much less than is called for by the present methods. The end point to be used will be a reduction of

from 50 to 75 per cent of the initial number, altho other points serve practically as well if not too near either end. The plate method can therefore be used and the organisms counted. Before adding the disinfectant, the number of bacteria in the initial water suspension is determined. To two tubes, disinfectant in two different concentrations is added. A third tube is treated like one of these and is kept at a temperature approximately 10° higher. After a convenient length of time, depending wholly upon the character of the organism and the strength of the disinfectant, the number of bacteria present in each tube is determined with the usual precautions as to neutralization of disinfectant and other details.

At the same time a single determination of K is made on phenol using the same bacterial culture. The value of n for phenol is found to be 6, and of θ , between 7 and 8. These apparently do not vary with the test organism. From the results from these four tubes, tested initially and finally, the ratio of the velocity constants of phenol and the unknown germicide, and the temperature coefficient and concentration exponent of the latter can be determined. Of course in a careful comparison one or two intermediate determinations of numbers would be made between the initial and final sets. Each additional determination allows of an independent determination of K , the results of which should then be averaged. As a matter of fact the mathematical and theoretical considerations are more accurate than the experimental work. Invariably when a large number of tests are made the average results are in conformity with the theory.

For the purpose of illustration an imaginary case has been worked out using the K , n , and θ values which have been calculated from a large number of experiments by Madsen and Nyman, Chick, and in the writer's laboratory. This illustration is given to show the mode of procedure, the amount of labor involved in the test, and the method of making the calculations.

To summarize, disinfectants differ in three independent ways and there are required three constants to indicate their relative efficiencies. These efficiencies are not determined by a comparison of one of the factors any more than the relative volumes of two pieces of wood are determined by a comparison of their lengths.

TABLE 1.
RESULTS OF TEST: ANTHRAX SPORES PER CUBIC CENTIMETER.

TIME (MINUTES)	PHENOL	MERCURIC CHLORIDE		
	5 per cent	1 per cent	0.5 per cent	
	20°	20°	20°	29°
0.....	125,000	125,000	125,000	125,000
2.....	.....	.....	.....	15,500
5.....	.....	7,900	.....	630
10.....	.....	545	9,250	4
15.....	.....	27	.....	.....
20.....	.....	.....	720	.....
30.....	.....	.....	60	.....
60.....	112,000	.....	.....	.....
120.....	101,000	.....	.....	.....
240.....	82,000	.....	.....	.....

CALCULATIONS.

Using the formula

$$\log \frac{B}{b} = KC^n t$$

expressing time in minutes, concentration in per cent, and using common logs, we obtain the following values of KC^n :

TABLE 2.
VALUES OF KC^n .

TIME (MINUTES)	PHENOL	MERCURIC CHLORIDE		
	5 per cent	1 per cent	0.5 per cent	
	20°	20°	20°	29°
0.....	.....	.....	.....	.....
2.....	.....	.....	.....	.453
5.....	.....	.240	.....	.440
10.....	.....	.236	.113	.460
15.....	.....	.244	.....	.....
20.....	.....	.....	.112	.....
30.....	.....	.....	.110	.....
60.....	.00080	.....	.....	.....
120.....	.00078	.....	.....	.....
240.....	.00077	.....	.....	.....
Average.....	.00078	.240	.112	.451

Having the value of $n=6$ already established for phenol, we obtain for this disinfectant

$$K_{20} = .000,000,05.
= .05 \times 10^{-6}$$

For the mercuric chloride we have at 20°:

$$KC^n = 0.240 \text{ at } C=1
KC^n = 0.112 \text{ " } C=0.5$$

Whence

$$n = \log \frac{.240}{.112} \div \log \frac{1}{0.5} \dots n = 1.08$$

$$K_{20} = 0.24 \text{ at } C = 1 \dots K_{20} = 0.24$$

$$0.24 \text{ " } C = 0.5$$

at 29° and $C = 0.5$

$$KC^n = .451$$

Whence

$$K_{20}^* = 0.953$$

$$9 \log \theta = \log \frac{K_{20}}{K_{20}^*} = 0.600$$

$$\log \theta = 0.067 \dots \theta = 1.17$$

Disinfectants vary in the rapidity of their action. Other things being equal, the disinfectant which accomplishes a certain destruction of bacteria in a given time is twice as efficient as one which accomplishes the same result in twice the time. This velocity factor we denote, in keeping with the nomenclature of physical chemistry, by K which we call the velocity constant. It indicates the velocity of the disinfection.

The second point of difference among disinfectants is the change in efficiency which they show with changing concentrations. Thus a 0.2 per cent mercuric chloride solution is twice as efficient (will do the work in half the time) as a 0.1 per cent solution. With phenol, however, in dilute solution, doubling the strength increases the efficiency or decreases the time 64 times. Conversely, halving the strength decreases the efficiency or increases the time 64 times. Other disinfectants have other ratios of increase with increasing strength. This factor we denote by the concentration exponent, n . This constant shows by what power of 2 the efficiency is increased if the concentration be doubled.

The third point of difference among disinfectants is their relation to temperature. Increasing the temperature 1° may increase the rapidity of disinfection by from 1.074 to 1.123 fold, or for 10° the change would be from 2 to 8 fold. The temperature coefficient, θ , shows how many fold the efficiency is increased by a rise of one degree in temperature.

Given these three constants of a disinfectant, results obtained at any one concentration, duration of time, and temperature can

be transformed to any other set of conditions by the following equations:

$$\log \frac{B}{b} = KC^n t$$

$$K_{T^\circ} = K_{20^\circ} \cdot \theta^{(T-20)}$$

<i>B</i>	Initial number of bacteria present.
<i>b</i>	Final " " " "
<i>t</i>	Elapsed time.
<i>C</i>	Concentration of disinfectant.
<i>K</i>	Velocity constant calculated at temperature of the experiment.
K_{T°	Same at any temperature T° .
K_{20°	Same at any temperature 20° .
<i>n</i>	Concentration exponent.
θ	Temperature coefficient.

The point of view which is taken here also somewhat simplifies our conception of antiseptic as distinguished from germicidal properties. It must be admitted that with our ordinary methods determining antiseptic properties there is no attempt made to determine whether there is or is not a true killing of the organism. The experiment is made with a very low concentration of disinfectant and proceeds for a long time. There is an apparent inhibition under these conditions, which may be really a true killing. It is evident from the form of our killing curve that a low rate of killing over a long time is just as efficient as a higher rate for a short period. There is no apparent reason thus far for the distinction between germicidal and antiseptic properties.

The real difficulty appears when two substances are compared in these respects. The fact, now well established, that one of the two may be the superior germicide and the other the superior antiseptic, leads at first thought to the belief that the two properties, germicidal and antiseptic, are unrelated and distinct. A brief consideration of the principles which have been laid down here will show that such a contention is at least unnecessary and probably unjustified.

Two disinfectants having different values of the concentration exponent, *n*, will have different relative efficiencies at different concentrations. Their efficiency-concentration curves may and in fact often do cross, so that at the point of crossing they are equal.

efficient, while above that point the one, and below that point the other, is superior. It follows then that antiseptic action, or true disinfection at low concentrations for long times, will show a relation between two disinfectants quite different from that shown at higher concentrations and shorter times. A disinfectant with a high value of n loses efficiency rapidly with dilution and hence is found to be a poor antiseptic, while one with a smaller value of n loses its power less rapidly with dilution. It has already been shown that decreasing the concentration of phenol one-half decreases its efficiency 64 times, its concentration exponent being six; while mercuric chloride with an exponent of one suffers a loss of efficiency of only one-half by similar dilution.

It is hoped to present this matter more fully in a subsequent paper and to support it with experimental data. For the present it is sufficient to point out that there is no necessity for the distinction between germicidal and antiseptic properties, and that the latter are equally determined by the fundamental constants that are here proposed.

An interesting corollary may also be drawn from this discussion. The velocity constant measures the velocity of the reaction between the disinfectant and the germ. With a given germ it is a measure of the power of the disinfectant. With a given disinfectant it is likewise a measure of the resistance of the organism. Hitherto all attempts to express the relation of bacteria to disinfectants, including heat, have been arbitrary. Death points have been sought when no such points exist. The rate of dying, whether under the influence of heat, cold, or chemical poison, is unfailingly found to follow the logarithmic curve of the velocity law, if the temperature be constant. This curve never reaches a zero value altho approaching it indefinitely. When in practice the bacteria are all killed this fact is interpreted mathematically to mean that, in the volume tested, the number is less than one. The common observation that the larger the initial number the longer the time required to kill is a proof of this view. It requires a greater percentage reduction to reduce the number to less than one, the larger the initial numbers. Therefore these death points are merely accidental, depending in the first place wholly upon the technic adopted

and again upon the chance of the last few survivors living or dying, when for a considerable period of time these chances are about equal.

The velocity constant, K , defines the properties of the logarithmic curve, and hence can be made to define such fundamental properties of an organism as its resistance to heat. To measure this function we would not attempt to determine a temperature at which the organisms all die (the non-existent thermal death point) but rather the rate of dying at any fixed temperature. If then we add to this determination a determination of θ which shows how this rate of dying increases with rising temperature, we have fully defined the thermal properties of the organism. A similar line of reasoning would apply to the relation of the organism to any other germicidal agent.

MILWAUKEE BUREAU OF ECONOMY AND EFFICIENCY

Created by Common Council
For the Investigation of Departmental Accounts and Methods.
Resolution Adopted June 14, 1910.

BULLETIN NO. 13

HEALTH DEPARTMENT

1. MILK SUPPLY

BY
SELSKAR M. GUNN

PREPARED UNDER THE DIRECTION OF
JOHN R. COMMONS

MILWAUKEE, WIS.
January 30, 1912

PUBLISHED SEMI-MONTHLY
Entered as Second Class Matter Oct. 27, 1911 at the
Post Office at Milwaukee, Wisconsin,
under the Act of July 16, 1894.

LETTER OF TRANSMISSAL
CITY OF MILWAUKEE,
BUREAU OF ECONOMY AND EFFICIENCY

Milwaukee, September

Dr. F. C. Kraft,
Commissioner of Health.
Dear Sir:

We submit herewith the report of the Bureau of Economy and Efficiency on the Milk Supply of Milwaukee, as required by the Health Department.

This investigation—into one of the most vital problems of the city—has included careful studies of the conditions of production, transportation, and distribution of milk, with special reference to the sanitary aspects of the question. Inspection has been made of milk plants, retail stores and farms; studies have been made of transportation; and many samples of milk have been tested bacteriologically. All these lines of investigation have been followed with the idea of finding out in how far the existing conditions are good or bad, and of discovering what measures should be made to assure to the citizens of Milwaukee a clean, safe milk supply.

As a result of this investigation a number of recommendations are made, the adoption of which, it is believed, will accomplish in a large measure the desired results.

Mr. Peter Rasmussen made the investigations of the milk plants, stores and farms; Messrs. A. C. Baer and A. G. Baer made the bacteriological investigations; Mr. Fred Merk, of the Health Department, made the maps; and Miss Aimee Zilmer and Miss Anna Zillman assisted in the preparation of the report. The thanks of the Bureau are due these persons for their interest and enthusiasm in this work.

The officials of the Health Department have assisted in this investigation and special thanks are due Dr. C. Ruhland and his assistant for extending all the facilities of the bacteriological laboratory, and to Mr. George J. Smith, the milk inspector, for assistance in collecting much of the material contained in the report.

Respectfully submitted,
(Signed) J. R. COMMONS, Director.
(Signed) B. M. RASTALL, Associate Director.

THE MILK SUPPLY OF THE CITY OF MILWAUKEE AND ITS CONTROL BY THE HEALTH DEPARTMENT

INTRODUCTION

No one who has made a careful and scientific study of the milk problem can fail to see the intimate relation of a city's milk supply to its health. Dirty and contaminated milk is one of the serious menaces to the public health. It is particularly dangerous to bottle-fed infants, and besides can act as a carrier of the organisms of scarlet fever, typhoid fever, diphtheria and tuberculosis. To tolerate conditions which produce such evil results is to encourage the maintenance of a high mortality among the preventable causes of death.

Milwaukee, like other cities, has its milk problem, and even if it is not as serious as in some other places, it is far from being solved and much remains to be done.

The general objects aimed at by cities in attempting to safeguard the milk to be consumed have been:

1. To have the milk of healthy cows handled by healthy attendants;
2. To minimize the danger of contamination of milk through dirt and specific disease producing organisms on the farm, during transportation, and while in the care of wholesale and retail dealers;
3. To maintain a reasonable and effective temperature standard;
4. To fix the age limit of the milk that may be sold; and
5. To prevent adulteration and sophistication and the use of preservatives, and to maintain milk and cream standards.

So much has been written on the dangers of diseased milk that it is not considered necessary here to repeat the well known truths. The purpose of this report is to discuss the general milk situation in Milwaukee, particularly from the point of view of Health department control; and to make recommendations as to how this control and supervision may be improved. It is not to be considered as a complete solution of all phases of the question. Much work will yet have to be done before the problems can be solved in a satisfactory manner.

With the growth of the city and the resulting increase in the "milk shed" and increase in the number of milk producers, the dangers are multiplied and the amount of inspection required. All milk processes must be increased proportionately.

Predictions of milk famines and great increases in the price of milk always follow upon recommendations that look to the sanitary control of a city's milk supply and the regulation of the unsanitary farmer and dealer, but experience has shown that as far as famines are concerned there is no real danger, and as for the increase in price, it has never been particularly excessive, and a sanitary milk is worth the increase.

GENERAL STATISTICS

The daily consumption of milk in Milwaukee is approximately 30,360 gallons, an average per capita consumption of about one pint per day. Besides this a large quantity of cream is consumed, 1,623 gallons by retailers alone; this figure does not include the vast amount shipped directly to ice-cream factories.

Approximately 1,900 dairy farms supply the city with milk and cream; less than 300 of these ship cream. This does not include those that supply ice-cream factories on wheels. No figures are available. About 95% of the milk comes from farms within forty-five miles of Milwaukee. Long shipments are usually longer and a large per cent. of the milk is shipped by creameries. Wholesale wagons, railroads and express lines carry 53%, 42%, and 5% of the milk respectively. As to the milk retailed by dealers near the city and the quantity of certified milk, all shipments are made under

eight gallons capacity. Most of the milk delivered to the consumers is from twenty-four and forty hours old.

The certified milk is controlled and regulated by the County Medical association. A small amount of high test milk from tuberculin tested herds is sold at prices as high as fourteen cents per quart; no special control is exercised over this quality of milk. All other milk is sold at six cents in summer and seven cents in winter.

There are 188 retail milk dealers distributing milk from wagons to homes and stores within the city limits. Stores handle from 20% to 25% of all the milk. They are especially important in the poorer districts where they enable people of scanty means to obtain fresh, cool milk at any time. Fourteen hundred stores were licensed in 1910, but there is reason to believe that there were no more than 1,100 or 1,150 stores selling milk at one time. These stores are well distributed, especially in the poorer districts.

RETAIL MILK TRADE

The 3,800 cans of milk and 1,800 gallons of cream are delivered to stores and homes by 188 dealers, using 412 milk wagons. The average load is seventy-eight gallons per wagon. Table I shows the general status of the milk trade.

Seventy-four per cent. of the milk sold is bottled. City retailers bottle 77% of the milk handled by them, retailers outside of the city 39% and retail farmers 25%. Fifty-nine per cent. of all the milk and 80% of the cream is pasteurized. Only city dealers, and usually only those who handle at least twenty-five cans per day, pasteurize; others consider it too expensive or unnecessary. None of the retailers outside of the city or retail farmers pasteurize.

Concentration of Output in Retail Milk Trade

The fact that 188 dealers distribute not quite 3,800 cans of milk does not seem to indicate concentration. A study of Table II shows, however, that 61% of the total milk supply is handled by ten dealers, 52% by four dealers and 36% by one dealer.

TABLE I.
MILK SUPPLY—MILWAUKEE.
GENERAL STATISTICS.

	Number of Dealers.	Number of Wagons.	Number Cans Handled.	MILK.			CREAM.		
				Number Cans Bottled.	Per- centage Bottled.	Number Cans Pasteurized, Bottled.	Number Gallons Handled.	Number Gallons Pasteur- ized.	Percentage Pasteur- ized.
City retailers	139	363	3,511	2,721.5	77	2,238	1,807.5	1,463	81
Retailers living outside city	22	22	175	68.5	39	0	16	0	0
Retail farmers	20	20	89	22.5	25	0	0	0	0
Not visited	7	7							
Totals	188	412	3,796	2,812.5	74	2,238	1,823.5	1,463	80

Capacity of can—8 gallons.

Score of City Milk Depots

Of the 139 milk depots within the city limits 130 were visited and scored. Seventeen retailers of milk who carried on their business outside of the city were also scored. The United States Department of Agriculture score card was used.

The depots scored an average of 43.8%. The scores of the small dealers were uniformly lower than those of the larger establishments. To show the scores and at the same time note the difference between large and small dealers, an arbitrary division was made. Here, and in all following tables, the handler of less than ten cans per day will be classed as a small dealer; all above, large dealers. (Table III)

Location of Milk Depots and Plants

Many milkmen seem to consider any available space appropriate for a milk depot, when on the contrary it should be carefully selected with attention paid to drainage, ventilation, light and surroundings. Milk depots were found next to barns and chicken-coops, in furnace rooms, and near toilets. One man was found bottling milk in a basement; the only light and ventilation were admitted by a small transom over a door. A tankful of rotten water, a foul smelling toilet, and a defective house-drain filled the room with most repulsive odors. This man insisted that he had as good a place for carrying on the milk business as anyone else in the city. This case is not given as representing the average condition.

A few basement rooms were satisfactory, but it is so difficult to properly light and ventilate a basement, to keep it free from odors and street dust with its pulverized horse droppings, as well as heaps of rubbish, that basements are as a whole justly condemned as milk depots. The Health department is working towards the elimination of basement milk plants.

Construction of Milk Rooms

Table IV, among other averages, shows the average score for construction of milk rooms.

The low score of outside dealers is largely due to lack of proper drainage facilities. The very fact that many milk rooms are located in basements suggests the undesirable construction of such quarters. Rough, cracked ceilings

TABLE II.
CONCENTRATION OF RETAIL MILK BUSINESS

	No. of Dealers.	No. cans of milk handled.	Average No. cans per Es- tablishment.
All dealers	188	3,796	20
Dealers within city limits...	139	3,510	25
Dealers within city limits handling over 10 cans per day	63	3,026	48
Dealers within city handling less than 10 cans per day	76	884	6
Ten largest dealers.....	10	2,303	230
Four largest dealers.....	4	1,975	443
Largest dealer	1	1,350	1,350

TABLE III.
SCORES OF MILK DEPOTS.

	No.	Aver. Score in %	Under 30%	30- 40%	40- 50%	50- 60%	60- 70%	70- 80%
Large city plants...	60	48.7	2	16	14	20	6	
Small city plants...	70	39.3	9	25	27	6	3	
Outside retailers.....	17	45.3	0	5	6	4	2	
Totals	147		11	46	47	30	11	
Maximum score given.....	93	%	Maximum possible.					
Minimum " "	12	%	Depots not scored..					
Average " "	43.8	%						

and walls, and faulty plumbing with sewer gas escaping were found in some instances.

**Light and
Ventilation**

The objectionable conditions found under this heading are largely a consequence of basement rooms. In numerous cases rubbish piled outside the windows, or dirty panes, excluded every ray of light; over some windows papers were tacked or shades were drawn to keep out the light. The wretched conditions are enhanced by the ignorance of the milk dealers; many depots having plenty of window space were dark because the lazy or negligent dealer failed to remove the collection of rubbish piled against his windows.

**Equipment of
Milk Plants**

Table V shows the small dealer at a disadvantage, as far as equipment is concerned; the small amount of trade does not warrant elaborate equipment. If there is an extra room—and most depots consist of only one room—it is used as a milk store room. In such close quarters, where washing and bottling are done, it is almost impossible to keep the room in a sanitary condition.

In a majority of instances the water used to wash bottles was not hot enough nor sufficient in quantity to cleanse the bottles properly. Half a dozen, besides those who pasteurize their milk, heat the water by steam. Three firms maintain steam washers. The majority depend on coal stoves or gas burners for their hot water supply. The equipment was generally found to be of sanitary construction, but the crowded conditions and the ignorance of dealers often nullified its good effect.

**Handling of
Milk at City
Milk Depots**

The scores of Table IV also show the unsatisfactory handling of milk. Milk arrives in the city between 8 A. M. and 4 P. M. Most of the rail shipments come in by 1 P. M. Small dealers trade almost entirely with wholesale wagons; large firms draw from wagons and railroad depots.

As long as the weather permits, in most places the milk is left exposed in the milk room. In summer, it is immediately

placed in cold water or on ice, except at plants pasteurized or bottled. Dealers pasteurize at time convenient to them.

Straining of milk is very imperfect; the cheese is in many cases filthy. Bottling is done by machine in six cases. Caps are generally inserted by hand. After the milk is put on ice. Ordinarily no ice is used on wagons. In very hot weather a little chipped ice is used. Milk is delivered between 2:30 A. M. and 9 A. M. outside retailers and a few city dealers get their milk from the farm soon after it is produced, and deliver it to the city twenty-four hours sooner than it would reach the city if handled in the usual way by railroad or wholesale. However, only about 150 cans daily are so delivered.

**Cleanliness of
Milk Rooms
and Equipment**

Not until ignorance, indifference and carelessness among milk handlers is overcome will the city expect to get a supply of safe milk. Good laws are useless if not properly enforced.

Table IV details the results of the inspection. The average score for cleanliness of wagons, rooms and equipment is 14.3. Out of a possible twenty-nine points for cleanliness, city dealers on the average scored 15.3; the small dealers 14.3; and retailers outside of the city 13.4.

Small and crowded rooms have before been noted as frequently being accompanied by filth. The city is now demanding that utensils used in connection with milk be sterilized is more often violated than obeyed. After being washed have been hastily washed in only warm water (to avoid being sterilized) they are usually rinsed in cold water. Bottles are not always satisfactorily drained.

Little attention is paid to the cleanliness of the rooms. In a large number of cases, caps were found exposed on shelves and boxes, or shelves and window sills, covered with dust at times moldy.

Three bottling machines were found in a very poor condition. Four dealers still use the old insanitary rubber tube machine. In the smaller plants the work of washing

TABLE IV.
DETAILS OF MILK DEPOTS SCORED.

NO.	Aver. Score, Location of Milk Room. (Possible 10)	Aver. Score, Construction Milk Room. (Possible 10)	Aver. Score, Equipment Milk Plant. (Possible 10)	Aver. Score, Light and Ventilation. (Possible 10)	Aver. Score, Handling and Storage. (Possible 20)	Aver. Score, Cleanliness. (Possible 29)	Aver. Score.
Large city plants (10 cans or more) 60	4.6	5.6	6.5	5.2	10.8	15.3	48.7
Small city plants (less than 10 cans) 70	3.1	4.8	5.5	5	8.9	14.3	39.3
Outside retailers 17	4.8	5.1	4.6	4.6	10.3	13.4	45
Totals 147	3.9	5.2	5.8	5.0	9.8	14.6	43.8

Maximum total score.....	93 points
Minimum " "	12 "
Possible " "	100 "

Eleven points are also allowed for condition of salesrooms and wagons. The marks given are not shown in a special column, although they are included in the total scores.

TABLE V.
EQUIPMENT OF MILK PLANTS.

	No.	Possible Score for Equipment—10.	Having Bottling Machines.		Without Bottling Machines.		Not Known.		Wash Utensils in Milk Rooms.		Hot Water in Kitchen.		Pasteurized.	Capping Machines.	Washing Machines.
			No.	No.	No.	No.	No.	No.	No.	No.	No.	No.			
Large city plants.... 60	6.5	51	7	2	48	6	18	3	3						
Small city plants.... 70	5.5	40	25	5	49	12	1	0	0						
Outside retailers..... 17	4.6	5	9	3	13	4	0	0	0						
Totals 147		96	41	10	110	22	19	3	3						

and utensils was usually attended to by the mill wife, though in some cases it was left to the child.

Pasteurizing machines and bottlers were usually but both were often located too near sources of such as engines and coal bins.

Delivery wagons were found in fairly good condition especially the city wagons. The outside dealers had constructed wagons. Milk cans were frequently carried and not washed.

Restaurants and hotels which buy milk in quantities from dealers are especially lax in washing and frequently return them filthy and vile smelling. Dealers were also found.

Large firms sell their surplus milk to candy factories, and cottage cheese makers.

In very few cases were clean milk suits worn. In a few instances are employees required to wash their hands handling the milk. Personal cleanliness is usually individual, rather than insisted upon by an authority.

It is evident from what has been written that milk depots are deficient. Much improvement could be made in a large number of places by the introduction of cleanliness. The need for very frequent inspection of depots is apparent, and it must be accompanied by education. If properly informed, would be willing to conform to rules and regulations. There are people in the market who have none of the necessary qualifications for inspection. Constant inspection and the proper enforcement of regulations will go a long way towards causing many incompetent and dangerous milk dealers to quit the business.

Milk Stores Of the 1150 stores (approximately 243 stores, or 21%, were investigated in the special investigation, made for the Commission, no score cards were used.

Two hundred and five stores sold 5,206 quarts of milk an average of 25.4 quarts per day. Assuming this average for the 1,150 stores sell a daily total of 913 eight-gallon milk cans. 24% of the total milk supply.

All milk from stores is sold in bottles, a regulation enforced by the Health department, though not embodied in the Milk Ordinance. About 40% to 50% of this is put up in pint bottles. In the Third ward several stores sold milk in half pint bottles. Eighty-five per cent. of the milk sold in thirty-two stores was pasteurized.

Table VI shows the kinds of stores selling milk and their comparative cleanliness. The ice boxes were usually clean—cleaner in fact than the stores. Small places were well kept, and their ice boxes showed lower temperatures than those of the larger stores. The chief objection to the condition of the ice boxes was that all kinds of perishable goods were kept in them together with the milk.

TABLE VI.
INSPECTION OF STORES.
GENERAL CLEANLINESS.

WINTER AND SPRING 1911.	Totals.	Total Percentage.
No. of stores.....	217	100
Grocery	157	71.4
Bakery	56	26.7
Other	4	1.8
Cleanliness of Store—		
Good	82	37.8
Fair	90	41.4
Poor	45	20.7

Table VII shows the condition with regard to the actual care of the milk in the stores at different times of the year. In many cases store keepers were careless with their milk during the spring and looked after it properly only when the hot weather came.

Temperature of Milk in Stores Temperatures of milk in ice chests were noted during May and June. Reasonable precautions were taken to keep milk at the legal temperature of 50 degrees F., but this seems impossible

UNIVERSITY OF MICHIGAN LIBRARIES

TABLE VII.
INSPECTION OF STORES.
GENERAL CARE OF MILK.

	WINTER AND SPRING 1911.				Visited before				June 1—15.			
					April 15.				April 28—29			
	No. of stores.	No. under 40° F.	No. 41° 45° F.	No. 46° 50° F.	No. 100%	No. 16.99%	No. 12.5%	No. 20.6%	No. 100%	No. 20.6%	No. 32	No. 100%
Total No. of Stores.....	112	100%	34	100%	39	100%	8	25%	0	0	38	97.4%
No. of Stores Milk in Ice Box, not iced.....	19	16.99%	7	20.6%	0	0	24	75%	1	2.6%	0	0
" " " " iced or in water.....	14	12.5%	10	29.4%	0	0	3	8.8%	0	0	0	0
" " " Milk on floor.....	30	26.8%	2	5.9%	0	0	0	0	0	0	0	0
" " " " shelves.....	45	40.2%	4	3.6%	0	0	0	0	0	0	0	0
" " " Condition not noted.....	4	3.6%	0	0	0	0	0	0	0	0	0	0

TABLE VIII.
TEMPERATURE OF MILK SOLD IN STORES.

	Month of inspection.	No. of stores.	No. under 40° F.	No. 41° 45° F.	No. 46° 50° F.	No. 51° 55° F.	No. 56° 60° F.	No. 61° 65° F.	No. 66° 70° F.
May, 1911.....	31	1	2	2	9	10	7	0	0
June.....	59	0	1	3	13	19	18	5	5
Totals.....	90	1	3	5	22	29	25	5	5

with the present type of ice box. The small ice box, opening on top, showed the lowest temperature. In May only 16.1% of the temperatures noted were within the legal standard, and in June but 6.7% in spite of the fact that all stores kept the milk on ice during that month. It is safe to say that with the average ice-box and under summer conditions at least 75% of the stores were unsuccessful in conforming with the temperature requirement. Table VIII gives the details of this work.

On the whole, milk is handled in a fairly satisfactory manner in the stores and presents one of the least difficult features of the milk situation. On account of the large amount of milk that passes through stores, constant inspection is imperative.

PRODUCTION OF MILK ON THE FARMS

If milk is polluted at its source, it is hopeless to try to deliver a really wholesome product to the consumer.

About 1,900 farms contribute to the city supply; 1,600 of these furnish milk and 300 cream.

It was not possible to visit many of the dairy farms; sixteen were scored, and through the courtesy of the Health department access was had to the records of 131 farms scored by the milk inspectors in 1910, making a total of 147 farms scored, or about 7.7% of the total number. Table IX shows the results of the scoring. The United States Department of Agriculture score card was used. The average score was 33.1. This low average needs no particular comment to persons acquainted with dairy farm inspection. From reliable information it is believed that the results obtained in scoring these 147 farms can be taken as applying in general to the farms supplying the city. Some are doubtless better and some worse. On the farms inspected both equipment and methods were poor and much behind the times. The most important thing to be done to bring up the standard and make the farmers clean up and make necessary alterations or additions to their present equipment, is constant inspection and instruction. This is the first step that should be taken by the Health department in its endeavor to improve the milk supply of the city. Occasional and desultory inspection will not bring about the desired results.

TABLE IX.
FARM SCORES.

	No. of Farms.	Aver. No. Cows per Farm.	Aver. No. gallons per Farm.	Score for equipment. Possible 40.	Score for T. methods. Possible 60.
Summer Months	61	11	25	13.0	21.9
Winter Months	70	9	22.7	13.0	20
April, 1911	16	11.5	25.8	10.5	20.9
	147	10.5	24.5	12.2	20.9

TABLE X.
STRIKING IMPROVEMENT ON THE DAIRY FARMS OF RICHMOND
DUE TO INSPECTION.

CLASS.	Percentage of all Dairy Farms Inspected during the Year.		
	1907.	1908.	1909.
Scoring below 30.....	6.0	...	...
Scoring between 30 and 40.....	13.2	...	...
Scoring between 40 and 50.....	26.3	.2	...
Scoring between 50 and 60.....	30.1	3.2	.3
Scoring between 60 and 70.....	18.3	27.6	20.8
Scoring between 70 and 80.....	5.2	43.1	51.7
Scoring between 80 and 90.....	.9	23.1	23.1
Scoring between 90 and 100.....	...	2.8	4.1
Average of all scores for year....	50.4	74.1	75.8

It must be regular and frequent, and the inspectors should act more as instructors than as inspectors, and aid the farmers in every way by advice and encouragement.

The experience of many cities in this work is very encouraging. The remarkable results attained in Richmond, Virginia, during the past four years in the improvement of the sanitary condition of the dairy farms by means of inspection, education and publicity are reproduced here in Table X, as an example of what would be possible in Milwaukee under the best conditions.

The Milk Commission of Philadelphia, in its recent report, recommends thirty-seven country inspectors for the 5,473 farms which supply that city. The commission allows for twelve inspections a year of each farm. Estimating on the Philadelphia basis, it would take thirteen men to do the same work for Milwaukee that is recommended for Philadelphia. The Philadelphia commission estimate is made, of course, looking towards an ideal inspection and it seems impractical to suggest the appointment of the proportionately high number of inspectors for Milwaukee.

It would take at least four inspectors to look after the 1,900 or more farms that supply the milk and cream to this city. This staff should be able to make four to five inspections per year of each place. The appointment of four country inspectors for Milwaukee cannot be considered in any way extravagant or disproportionate to the population. Table XI shows the number of people in the city to each country milk inspector in twelve large cities. The number of farms per inspector in ten cities is shown in Table XII. It will be noticed that Milwaukee has an unfavorable position in both tables. It is really more favorable than it should be as the two so-called country inspectors employed by the Health department, spend only a part of their time on dairy work and devote the major portion of their time to inspection and analytical work in the city.

Table XIII shows the percentage of farms inspected yearly in twelve large cities and the number of times of inspection per year. Milwaukee's showing is again unsatisfactory. In

TABLE XI.
NUMBER OF PEOPLE IN CITY TO EACH COUNTRY MILK

1. Washington.....	1	Inspector to
2. Richmond	1	" "
3. Los Angeles	1	" "
4. Seattle *	1	" "
5. Cleveland	1	" "
6. Boston	1	" "
7. Detroit	1	" "
8. New York	1	" "
9. Milwaukee †	1	" "
10. San Francisco	1	" "
11. Baltimore	1	" "
12. Chicago	1	" "

* Inspectors do all the city work as well.

† While called country inspectors, they devote most of their time to city milk work, and also analyze all samples collected by them.

TABLE XII.
COUNTRY INSPECTION OF FARMS FURNISHING MILK

	No. of Country Inspectors.	No. of Farms.
1. Richmond	2	132
2. Washington	6	1,091
3. Seattle †	3	700
4. Detroit	4	2,000
5. Milwaukee *	2	1,600
6. Cleveland	6	3,500 to 6,000
7. Boston	6	6,000
8. Baltimore	2	2,300
9. New York	32	44,000
10. Chicago	7	12,000

† Inspectors do all the city work as well.

* While called country inspectors they devote most of their time to city work.

all the cities except Baltimore and Milwaukee, the sanitary conditions of dairy farms must be approved before milk is sent to the city. This is a particularly strong point and is not possible of attainment unless a staff of country inspectors is maintained.

It has been pointed out that about 59% of the entire milk supply is pasteurized, and that 80% of the cream is similarly treated (not including cream for ice-cream factories). On account of the importance of pasteurization special attention was paid to this subject. The average score of pasteurizing plants was 56.1. This is about twelve points higher than the average for all milk plants. Only the larger plants pasteurize, and these plants are generally conducted in a much more sanitary manner than are those of their smaller competitors. Bacteriological tests of the efficiency of pasteurizing were also made during the month of July. One plant was tested four times; sixteen, three times; two, twice; and two, once. In all, twenty-one plants were tested, and fifty-nine complete investigations made.

TABLE XIII.
FARM INSPECTION.

	Per Cent. Inspected Annually.	No. of Times per year In- spected.	Improve- ment due to Score card.	Minimum Score Require- ment.	Must sanitary conditions be approved before milk is sent to City.
Cleveland	100%	4	Yes	Yes	Yes
Detroit	100%	..	Yes	No	Yes
Chicago	50%	No regular time	Yes	No	Yes
Los Angeles	100%	12-36	Partly	No	Yes
Richmond	100%	12	Partly	Yes	Yes
Washington, D. C.....	100%	2-4	Partly	No	Yes
New York	100%	1½	Partly	No	Yes
Boston	Just begun	1	Yes	Yes	Yes
Seattle	75%	4	Yes	Yes	Yes
San Francisco	100%	4	Yes	Yes	Yes
Milwaukee.....	20-25%	No regular time	Just adopted	No	No
Baltimore	7%	—	Yes	No	No

Table XIV shows the names of the different machines, the temperature of pasteurization at the different temperatures, the temperature of the milk coming from the coolers, the cooling, and the scores. Table XV summarizes the findings for flash pasteurization temperatures. It will be noted that of fifty-two tests on flash machines, thirty-five or 67% were run at temperatures under 160 degrees. Table XVI summarizes the findings with regard to the temperature of the milk coming from the cooler. Twelve out of fifty-nine observations showed temperatures over the legal limit of fifty degrees. This is due to the fact that some dealers use only lake water for their milk. The temperature of this water is extremely high and it cannot be relied upon to cool milk, particularly in the summer months. The importance of thorough cooling cannot be emphasized. All plants of this kind should have a standard in cooling their milk down to the legal standard.

The efficiency of pasteurization, as measured by the decrease in the number of bacteria in the raw milk and the time it came from the machine, was on the whole satisfactory. This was partly due to the fact that the raw milk in most cases had excessive numbers of bacteria present and that the percentage of removal by the heating treatment was very large. Table XVII shows the results of the examination of raw milk delivered to the pasteurizers. Of the 54 samples analyzed, fifty-four, or 91.8%, had more than 250 bacteria to the cubic centimetre, and forty-nine or 81.8% more than a million.

Forty-one samples were taken from "comebacks" from bottles which had been returned from the wagons. Twenty of these or 48.8% showed more than 250 bacteria per c. c. The results are given in Table XVIII. The necessity for icing milk on the wagons is brought out by the analyses.

A great deal of sour milk is returned by the dealers to the farmers. This waste could undoubtedly be greatly reduced if the milk were produced and transported under satisfactory conditions. Poor methods in cooling and bottling milk result in a number of cases to practically undo the benefits of pasteurization.

TABLE XIV.

FLASH PASTEURIZERS.

Make of Machine.	No. of cans of milk Plant. pasteurized.	No. of	Past. Temp.			Temp. of milk coming from cooler.			Method of cooling.	Score of milk depot.
			1	2	3	1	2	3		
Reed	1	35	166	148	155	50	45	40	Brine	64
"	2	16	160	160	160	45	45	45	Ice w. and city w.	57
"	3	15	160	154	165	50	60	50	City water	39.5
"	4	16	162	168	...	45	45	...	Ice w. and lake w.	32.5
"	5	22	160	164	160	39	50	50	Ice water	67
"	6	15	158	155	160	40	50	50	Ice w. and city w.	60
"	7	8	158	155	...	50	50	...	Ice w. and city w.	47.5
"	8	20	160	155	160	50	50	50	Ice and lake w.	64
Gehl	9	22	160	165	155	55	53	50	City water	..
"	10	50	150	130	162	58	58	48	City water	59
"	11	50	{ 156	160	170	62	60	50	Ice w. and city w.	41.8
"	12	20	152	155	155	60	50	46	City water	49
Commercial	13	400	178	160	171	43	36	40	City w. and brine	43.5
"	14	25	170	155	...	52	45	..	Ice w. and city w.	42.5
"	15	16	152	...	...	50	...	..	Ice water	..
Farrington	16	12	154	156	155	40	42	40	Ice w. and lake w.	53
"	17	32	155	160	158	50	48	45	Ice water	59
Miller-Tyson	18	100	176	160	178	50	45	55	Ice w. and brine	71.7
Miller	19	100	164	170	163	46	52	58	Ice w. and city w.	58.5

HOLDER PASTEURIZERS.

Farrington (22 minutes)	20	150	142	146	146	36	36	36	36	36	36	Cold w. and brine	62.5
Wilman (26 minutes)	21	1,600-1,700	145	145	145	30	31.5	32	31.5	32	32	Brine and ice w.	93

Temperatures given in this chart are those noted by the bacteriologist who made the tests.

TABLE XV.
TEMPERATURE OF FLASH PASTEURIZATION

Temp. Fahrenheit.	No. of Observations
130-140.....	1
141-150.....	2
151-155.....	14
156-160.....	18
161-165.....	7
166-170.....	6
171-180.....	4
Totals.....	52
Maximum temperature observed.....	
Minimum temperature observed.....	

TABLE XVI.
TEMPERATURE OF MILK IN COOLER.

Temp. Fahrenheit.	No. of Observations
31-35.....	4
36-40.....	9
41-45.....	12
46-50.....	22
51-55.....	6
56-60.....	5
61-65.....	1
Totals.....	59

TABLE XVII.
RAW MILK AT PASTEURIZING PLANTS.

No. of Bacteria per C. C.	No. of Observations.	Per Cent.
Less than 10,000.....	0	.0
10,000- 50,000	1	1.6
50,000-100,000	1	1.6
100,000-250,000	3	5.0
250,000-500,000	6	10.0
500,000 and over.....	49	81.8
Totals	60	100.0

TABLE XVIII.
"COMEBACKS."

No. of Bacteria per C. C.	No. of Observations.	Per Cent.
Less than 10,000.....	1	2.4
10,000 to 50,000.....	9	21.9
50,000 to 100,000.....	4	9.8
100,000 to 250,000.....	7	17.1
250,000 to 500,000.....	4	9.8
500,000 and over.....	16	39.0
Totals	41	100.0

izing; in some instances there were found to be in the bottled milk than in the raw milk before. Not enough care is taken in some places to keep thoroughly clean or to wash the bottles efficiently. Operators of pasteurizers merely look upon the machine to retard souring. The sanitary aspect of the process is looked. It is extremely doubtful whether any tests of bovine origin that are present in the milk would be by the temperature used by some dealers.

Pasteurization may be dangerous unless properly supervised. There is need of constant inspection, control by laboratory tests, and proper ordinances defining and regulating practice.

TRANSPORTATION OF MILK

Under normal conditions milk is brought into the city as follows:

Wagons	2,000 cars
Milwaukee Northern Electric R. R..	350 cars
Chicago & Northwestern R. R.....	145 cars
C. M. & St. P. R. R.....	1,400 cars

There is some fluctuation in the above and the demand of the city is by no means stable. Shortness of cream section and heavy demands for cream for ice cream cause milk to be brought at times from considerable distances. It is probable that a great deal of milk is brought by farmers within comparatively short distances and sold by them to cheese factories, condenseries and creameries which might be diverted into the city market. The farmers might be willing to sell their milk to the city if they could get a better price for it.

The milk brought in by wagon is in the hands of three men, who own fifty-three wagons. They collect the milk from the country and deliver it to the dealers in the city. The price is fifteen to eighteen cents per can for transportation. The wagons are covered but are usually without ice.

wagons come from ten to sixteen miles and the trips last from three to seven hours, varying of course with the weather and condition of the roads. To save space on the wagons cans that are not completely filled are at times filled up with milk from other farms. Milk is picked up by drivers of the wagons, and in order to save time, farmers living on side roads, carry their milk down to the main road and leave it in some instances unprotected from man or elements until the wagon comes along. Some milk is left exposed for a considerable time.

The condition on the electric and steam railroads is not very dissimilar. Milk is left at the depots and eventually taken up by the milk train, transported uniced to the city and then carted to the dealers. One or two special consignments are iced during hot weather. The rates paid for the transportation of milk on the electric and steam railroads naturally vary a great deal with the distance the milk is carried.

The amount of milk shipped by electric lines is small. It would undoubtedly be increased if the embargo prohibiting the transit of freight into the city were lifted. All milk brought by such lines has to be unloaded at the city limits and transferred by wagons to its final destination.

Under the present transportation arrangements the temperature of the milk is given practically no consideration. It is given plenty of opportunity to become heated before it arrives in the city even if originally cool when delivered by the farmer, and it is apt to be on a fair way to souring, if it has not already reached that condition.

Table XIX gives the results of seventy-four temperature readings of milk made at the railroad terminals in the city on the arrival of milk trains. The tests were made in May. In no instance was a sample found conforming to the legal standard. It was not to be expected under the conditions of shipment. Fifty-eight of the seventy-four samples were above 60 degrees and nine samples had temperatures over 70 degrees. It is not to be thought that the high temperature of the milk is due entirely to the methods of transportation.

TABLE XIX.

MILK TEMPERATURES.

Samples taken at City R. R. Terminals.

	No. of samples below 50°	No. 50°-55°	No. 55°-60°	No. 60°-65°	No. 65°-70°	No. 70°-75°	No. 75°-80°	Maxi- mum Temp.	Mini- mum Temp.	Total Samples.
May 25th, 1911— Outside temp. 76° F. at 8:30 A. M... Shipped 14 miles.	0	2	1	4	4	1	0	70°	52°	12
May 26, 1911— Outside temp. 80° 8-11 A. M..... Shipped 16 miles.	0	0	0	5	0	0	0	64°	60°	5
" 21 "	0	0	1	4	4	1	0	74°	58°	10
" 27 "	0	0	0	2	3	4	2	78°	60°	11
" 30 "	0	0	0	0	6	1	0	74°	66°	7
" 42 "	0	0	0	3	2	0	0	68°	62°	5
Misc. samples—Temp. 74°	0	1	2	16	5	0	0			24

Table XX shows the results obtained in May by Health department inspectors, who took the temperature of milk on the road as it was taken up from the farms by a wholesale wagon.

TABLE XX.

TEMPERATURE OF THE MILK AS COLLECTED BY WHOLESALE WAGON
ON ITS WAY TO THE CITY.

May 28, 1911.

No. of samples.	Outside Temp- erature.	% at 50° F. and below.	51° to 55°	56° to 60°	61° to 65°	66° to 70°	71° to 75°	76° to 80°
30	76°	6.6	3.3	23.3	26.9	23.3	13.3	3.3
Minimum temperature, 48°.					Maximum temperature, 78°.			

Only 6.6% of the milk was below 50°, 68% was above 60° and 16.6% over 70°. It is evident that the farmer has much to learn concerning the necessity of cooling his milk. Tables XXI, XXII and XXIII show the conditions of collection for three wholesale wagons, and the temperatures of the milk at the times of collection and delivery. These tables again point out the high temperatures at which milk is delivered to the wagon and also demonstrate the fact that before the milk is finally delivered to the dealer in the city its temperature has greatly increased. The increases would have been even greater if the tests were made on days when the air temperatures were higher.

Table XXIV shows the temperatures of milk at the time of collection by an electric railway.

The transportation of milk presents peculiar difficulties. It is a problem by itself. It is essential that milk produced under sanitary conditions and handled in the city in a like manner, should be safeguarded in transit in every way. The sanitary chain is no stronger than its weakest link. In order that transportation may not cause a deterioration in the milk there should be: (1) proper facilities for storing the milk until it is collected, (2) rapid delivery to the city in suitable iced wagons or refrigerator cars, and (3) absolute cleanliness and non-interference with the milk during transit.

COLLECTION BY WHOLESALE WAGONS.

August 29, 1911.

Showing Conditions of Collection and Temperature of Milk at Time of Collection and Delivery.

Shipper's No.	Place Where Milk Collected.	Distance in Miles Brought by Shipper to Wholesaler.	Time Collected.	Time Delivered.	Temperature When Collected.	Temperature When Delivered.
			A. M.	A. M.		
1.	At farm of driver of wagon.	2	7:00	11:00	50°	64°
2.	" " " "	2	7:00	11:00	52°	63°
3.	" " " "	2	7:00	11:00	50°	62°
4.	" " " "	1/2	7:00	11:00	53°	63°
5.	" " " "	1	7:00	10:45	56°	63°
6.	Cold water tank at farm.		7:10	10:15	50°	64°
7.	" " " "		7:15	10:15	48°	60°
8.	" " " "		7:20	10:15	50°	60°
9.	" " " "		7:25	10:15	54°	61°
10.	" " " "		7:30	10:15	56°	64°
11.	" " " "		7:35	10:15	57°	66°
12.	" " " "		7:40	10:15	51°	67°
13.	" " " "		7:45	10:15	49°	62°
14.	" " " "		7:50	10:15	52°	64°
15.	" " " "		7:55	10:15	50°	64°
16.	" " " "		8:00	10:15	56°	64°
17.	" " " "		8:15	10:15	54°	63°
18.	" " " "		8:15	10:45	55°	62°
19.	" " " "		8:20	10:45	50°	62°
20.	" " " "		8:25	10:45	51°	62°
21.	" " " "		8:30	10:45	53°	64°
22.	" " " "		8:35	10:45	50°	61°
23.	" " " "		8:40	10:45	54°	64°

Air temperature at first collection, 56°.

Air temperature at last delivery, 68°.

TABLE XXIII.
COLLECTION BY WHOLESALERS WAGONS.

Showing Conditions of Collection and Temperature of Milk at Time of Collection and Delivery.
August 30, 1911.

Shipper's No.	Place Where Milk Collected.	Distance in Miles Brought by Shipper to Wholesaler	Time Collected. A. M.	Time Delivered.	Temperature When Collected.	Temperature When Delivered.
1.	From farm at roadside.....	$\frac{3}{4}$	6:30	1:05 P. M.	56°	64°
2.	" " ".....	$1\frac{1}{2}$	6:30	*	57°	*
3.	" " ".....	$\frac{3}{4}$	6:30	*	58°	*
4.	Cold water tank at farm.....	...	6:35	11:30 A. M.	52°	58°
5.	From farmer at roadside.....	1	6:50	12:30	57°	62°
6.	Cold water tank at farm.....	...	6:55	12:50	56°	60°
7.	" " ".....	...	6:55	12:15	60°	62°
8.	From farmer at roadside.....	$1\frac{1}{2}$	7:00	12:50	56°	62°
9.	" " ".....	$1\frac{1}{2}$	7:10	*	55°	*
10.	" " ".....	$1\frac{1}{2}$	7:15	11:30	45°	56°
11.	" " ".....	$\frac{1}{4}$	7:20	11:20	53°	58°
12.	" " ".....	2	7:20	11:20	48°	60°
13.	" " ".....	$1\frac{1}{2}$	7:25	*	49°	*
14.	" " ".....	$\frac{1}{2}$	7:25	11:45	61°	63°
15.	Cold water tank at farm.....	...	7:30	12:00	56°	62°
16.	From farmer at roadside.....	$1\frac{1}{2}$	7:35	*	62°	*
17.	From roadside (unprotected).....	$\frac{1}{4}$	7:35	12:00	58°	60°
18.	From farmer at roadside.....	$1\frac{1}{4}$	7:40	11:45	59°	56°
19.	" " ".....	$\frac{3}{4}$	8:10	12:15	60°	62°
20.	Cold water tank at farm.....	...	8:20	12:15	56°	60°

TABLE XXIV.
COLLECTION BY ELECTRIC RAILWAY.
September 1, 1911.

Showing Temperatures of Milk at Time of Collection.

Station Name or Number.	Time. A. M.	Temperature of Milk in degrees F. when picked up by train. Only one reading of temperature is from any one shipper.
Port Washington..	8:25	67, 63, 64, 66
24	8:30	69, 69
23	8:35	70, 64
22	8:50	82, 76
21	9:00	68, 78
18	9:15	78, 70, 67, 50, 68, 66, 48, 66, 78, 69, 56, 76, 67, 67
17	9:20	68, 70, 72
16½	9:30	60, 58, 64, 66, 56, 64, 50, 52, 64, 66, 64, 70
16	9:50	66, 69, 65, 66, 56, 76, 56, 54, 64, 50, 66, 50, 50, 66
15	9:55	66, 50, 64, 65, 66, 50, 50, 50, 70, 71, 73, 67
14	10:00	66
Thiensville	10:05	67, 67, 56, 55, 64, 66, 65
Mequon.....	10:10	58, 66, 68, 64
9.....	10:20	68, 70, 56, 66
8.....	10:23	66
Outside temperature at start, 80°.		Distance, 30 miles.
Outside temperature at finish, 88°.		Time consumed, 2 hours.

Stations where milk is taken on are merely platforms situated where the roads cross the tracks. The milk is absolutely unprotected on these platforms. In one case it was discovered that the milk had been standing on the platform for 1 hour and 15 minutes before picked up by the train.

The problems of transportation will not be solved until all milk is shipped in sealed cans, icing stations provided at depots, and refrigerator cars used. The solution of the problem is eminently associated with the economic phase of the milk problem.

BACTERIOLOGY OF MILWAUKEE MILK SUPPLY

With an idea of obtaining some insight into the number of bacteria in Milwaukee milk, samples were taken from stores, wholesale wagons, milk plants, and railroad receiving stations.

Table XXV gives the result of the examination of 117 samples of milk as taken from wholesale wagons. Eighty-two samples, or 70.1%, had more than 250,000 bacteria per c. c.,

TABLE XXV.
WHOLESALE WAGONS.
 Bacteria per cubic centimetre.

	Number.
Less than 10,000.....	0
10,000 to 50,000.....	6
50,000 to 100,000.....	7
100,000 to 250,000.....	22
250,000 to 500,000.....	19
500,000 to 1,000,000.....	16
1,000,000 to 5,000,000.....	32
5,000,000 and above.....	15
Totals	117

TABLE XXVII.
RAILROAD RECEIVING STATIONS.
 Bacteria per cubic centimetre.

	Number.
Less than 10,000.....	0
10,000 to 50,000.....	3
50,000 to 100,000.....	7
100,000 to 250,000.....	11
250,000 to 500,000.....	8
600,000 to 1,000,000.....	8
1,000,000 to 5,000,000.....	10
5,000,000 and over.....	5
Totals	52
Highest count	10,800
Lowest count	1

TABLE XXVI.

DETAILS OF BACTERIOLOGICAL ANALYSES OF MILK FROM WHOLESALE WAGONS.

	Less than 10,000	10,000 to 50,000	50,000 to 100,000	100,000 to 250,000	250,000 to 500,000	500,000 to 1,000,000	1,000,000 to 5,000,000	5,000,000 and above	Totals	Maximum	Minimum
1.....	0	0	1	1	2	1	5	4	14	16,200,000	95,000
2.....	0	0	0	4	0	0	0	0	4	230,000	140,000
3.....	0	0	0	5	3	2	2	1	13	6,300,000	220,000
4.....	0	0	0	0	1	2	3	1	7	9,525,000	485,000
5.....	0	0	0	2	1	0	4	2	9	7,440,000	125,000
6.....	0	1	1	2	0	0	1	1	6	16,200,000	45,000
7.....	0	2	1	0	0	1	3	1	8	5,900,000	20,000
8.....	0	0	0	0	0	0	1	1	2	6,300,000	1,665,000
9.....	0	0	2	3	4	3	4	0	16	4,180,000	60,000
10.....	0	0	0	0	4	0	2	3	9	13,900,000	270,000
11.....	0	1	0	0	0	3	5	1	10	8,400,000	40,000
12.....	0	2	2	5	4	4	2	0	19	1,610,000	40,000
Totals.....	0	6	7	22	19	16	32	15	117		

forty-seven, or 40.2%, more than one million, and fifteen, or 12.8%, more than five million. Comment seems unnecessary. It indicates gross negligence or ignorance, or both. The details of this bacteriological investigation of the milk from wholesale wagons are given in Table XXVI.

Compare the above with the record of Richmond, Virginia, for 1910. Although a southern city and having to contend with hot weather for a great part of the year, not a single sample out of 1,610 samples examined in that year showed over 500,000 bacteria per c. c. This shows the result of inspection, co-operation, and education.

Table XXVII gives the results of the examination of fifty-two samples of milk taken at the railroad receiving stations. Twenty-nine samples, or 59.4%, had more than 250,000 bacteria per c. c., fifteen, or 28.8%, one million or more, and five, or 9.6%, more than five million. With both wagon and railroad milk counts of over ten million were not uncommon.

Table XXVIII gives the analytical results of forty-eight samples of milk taken from stores. Twenty samples, or 41.6%, showed more than 250,000 bacteria per c. c., seven, or 14.6%, one million or more, and two, or 4.2%, more than five million. The majority of store samples were of pasteurized milk.

Table XXIX shows the results of bacteriological examinations of ice cream and is introduced here to indicate the need for work along this line.

Bacteriological examinations of milk are made by the bacteriologist of the department, but he is kept so busy with other routine work that he has very little time for milk.

The following table shows the number of samples of milk examined bacteriologically during the past five years:

1906	97
1907	161
1908	55
1909	54
1910	110

The importance of bacteriological examinations of milk has been well demonstrated in a large number of cities, and such

TABLE XXVIII.
STORES.
Bacteria per cubic centimetre.

	Number.	Per Cent.
Less than 10,000.....	0	0
10,000 to 50,000.....	13	27.1
50,000 to 100,000.....	8	16.66
100,000 to 250,000.....	7	14.6
250,000 to 500,000.....	8	16.66
500,000 to 1,000,000.....	5	10.4
1,000,000 to 5,000,000.....	5	10.4
5,000,000 and above.....	2	4.2
Totals	48	100.00
Highest count	15,000,000	
Lowest count	19,000	

TABLE XXIX.
BACTERIOLOGICAL EXAMINATION OF 26 SAMPLES OF ICE CREAM.

No. of Bacteria per c. c.	No. of observations.	Per Cent.
100,000 to 250,000.....	1	3.8
250,000 to 500,000.....	1	3.8
500,000 to 1,000,000.....	4	15.4
1,000,000 to 5,000,000.....	15	57.7
5,000,000 to 25,000,000.....	2	7.7
25,000,000 or over.....	3	11.5
Totals	26	100.0
Highest count	8,000,000,000	
Lowest count	200,000	

examinations have been found to be a very useful the campaign for a clean and properly handled milk.

Milwaukee has a bacteriological standard of 250,000 per c. c. How poorly it is lived up to has been already in this report. Pasteurizing plants can be kept as efficient if subjected to periodic bacteriological tests.

There is an increasing need and demand for bacteriological examinations to be made of dairy products, such as cream and butter. A sanitary bacteriologist could be kept, indeed, doing the work of the Food division of the health department.

Frequent chemical tests for fats, total solids and bacteria are always accompanied by a decrease in the sophistication and adulteration of milk, and frequent bacteriological and sediment tests are followed by a decrease in the number of bacteria and the amount of dirt found. This signifies a consequent improvement in the sanitary condition under which the milk is handled.

Table XXX shows the number of bacteriological examinations of milk per 1,000 population made in twenty-four cities. It will be noted that Milwaukee stands twentieth in the list of twenty-four.

CHEMICAL ANALYSES OF MILK

The analyses of milk and cream are made made by sanitary inspectors. The number of samples analyzed in the past five years is given in the following table. The analyses are mostly butter fat determinations. Total solids are estimated by formula, except in special instances:

	Milk.	Cream.
1906	4,897	3,044
1907	5,067	2,935
1908	8,640	4,033
1909	8,272	5,083
1910	8,106	4,768
	34,982	19,863

It can readily be seen that the time consumed in making this large number of analyses is very considerable.

TABLE XXX.
NUMBER OF SAMPLES OF MILK EXAMINED BACTERIOLOGICALLY.
Per 1,000 of Population in 24 Cities.

City.	Year.	Samples tested per 1,000 Population.
1. Fall River, Mass.....	1910	28.84
2. New Haven	1909	27.58
3. Nashville	1910	16.87
4. Richmond	1910	12.58
5. Boston	1909	9.64
6. Memphis	1909	9.53
7. Buffalo	1910	8.74
8. Scranton	1910	7.85
9. Rochester	1910	5.15
10. Cleveland	1909	4.64
11. Chicago	1910	4.59
12. New York	1908	2.58
13. Seattle	1909	2.33
14. San Francisco	1909-1910	1.58
15. Spokane	1910	0.83
16. Bridgeport, Conn.	1910	0.54
17. Cincinnati	1909	0.53
18. St. Louis	1908-1909	0.52
19. Minneapolis	1909	0.38
20. Milwaukee	1910	0.29
21. St. Paul	1909	0.19
22. Detroit	1910	0.11
23. Portland	1910	0.07
24. Toledo	1910	0.06

3.94% of the samples of milk were below the 3% standard and 6.48% of the samples of cream were 18% butter fat standard.

Table XXXI gives a comparison of the number of cream analyzed per 1,000 population in fourteen cities listed separately in their annual reports the number of samples of milk and cream analyzed. It will be noted that Milwaukee analyzes many more samples of cream than any other city in the list. Table XXXII gives the same information for the same cities. With the exception of Kansas City, Milwaukee analyzed more samples than any other city. Table XXXIII gives information of twenty-seven cities, only the milk and cream analyses are here combined, as they were not given separately in many reports. Milwaukee stands first in the list.

There is no question that good results have been obtained from the chemical work done on milk and cream by the Health Department, but when it is remembered that the men who do practically all of the work, also have to do all the inspection and clerical work connected with milk and its products, it seems that too much emphasis has been laid on the chemical work on milk and cream. Furthermore, the number of samples analyzed seems altogether disproportionate to the amount of milk and cream consumed in the city. This chemical work should be done by milk inspectors, but by a chemist who is not in the laboratory.

TABLE XXXI.

NUMBER OF SAMPLES OF CREAM EXAMINED CHEMICALLY.

Per 1,000 of Population in 14 Cities.

City.	Year.	Samples tested per 1,000 Population.
1. <i>Milwaukee</i>	1910	12.75
2. <i>Denver</i>	1910	4.43
3. <i>Spokane</i>	1910	3.46
4. <i>Washington, D. C.</i>	1909	2.9
5. <i>St. Louis</i>	1909	2.77
6. <i>Grand Rapids</i>	1910	1.74
7. <i>Minneapolis</i>	1909	1.04
8. <i>Kansas City</i>	1910	.76
9. <i>Worcester</i>	1910	.68
10. <i>Rochester</i>	1910	.19
11. <i>New York</i>	1908	.11
12. <i>Detroit</i>	1910	.08
13. <i>Cleveland</i>	1909	.07
14. <i>Buffalo</i>	1910	.01

TABLE XXXII.

NUMBER OF SAMPLES OF MILK EXAMINED CHEMICALLY.

Per 1,000 of Population in 14 Cities.

City.	Year.	Samples tested per 1,000 Population.
1. <i>Kansas City</i>	1910	26.27
2. <i>Milwaukee</i>	1910	21.68
3. <i>Rochester</i>	1910	16.53
4. <i>Washington, D. C.</i>	1909	10.82
5. <i>Worcester</i>	1910	10.27
6. <i>Grand Rapids</i>	1910	9.00
7. <i>Cleveland</i>	1909	8.91
8. <i>Denver</i>	1910	5.96
9. <i>St. Louis</i>	1908-1909	5.46
10. <i>Spokane</i>	1910	4.27
11. <i>Minneapolis</i>	1909	3.23
12. <i>Detroit</i>	1910	2.92
13. <i>New York</i>	1908	1.48
14. <i>Buffalo</i>	1910	.67

TABLE XXXIII.

NUMBER OF SAMPLES OF MILK AND CREAM EXAMINED CHEMICALLY
PER 1,000 OF POPULATION IN 27 CITIES.

City.	Year.	Samples tested per 1,000 Population.
1. Milwaukee	1910	34.43
2. Kansas City	1910	27.03
3. Boston	1909	21.97
4. Lowell	1910	21.63
5. New Haven	1910	21.04
6. Chicago	1910	18.37
7. Rochester	1910	16.72
8. Toledo	1910	14.55
9. Washington, D. C.	1909	13.72
10. Richmond	1910	12.53
11. New Orleans	1909	12.14
12. Worcester	1910	10.95
13. Grand Rapids	1910	10.74
14. Denver	1910	10.39
15. Cleveland	1909	8.97
16. St. Louis	1908-1909	8.23
17. Spokane	1910	7.73
18. San Francisco	1909-1910	6.79
19. Seattle	1909	6.77
20. Scranton	1910	6.5
21. Nashville	1910	5.57
22. Minneapolis	1909	4.27
23. Portland	1910	3.24
24. Detroit	1910	3.00
25. New York	1908	1.59
26. Buffalo	1910	.68
27. Cincinnati	1909	.37

CONCLUSIONS

It is evident from the above considerations of the milk situation in Milwaukee that much has yet to be done to bring the standard up to a point where it can be considered satisfactory. It is realized that any solution of the milk problem such that a clean and safe milk can be assured to all is dependent on a number of factors. One of these is the proper adjustment of the economic questions that are involved. It costs more to produce clean than dirty milk and a need for a thorough study into the economic side of the question is imperative. At the present time the careful producer and dealer is working under a serious disadvantage; he gets no more for his milk than does the slovenly and careless handler, although it costs the former more to produce and handle. This is manifestly unfair. This unfairness can never be overcome unless certain minimum standards are set up which must be attained by all who wish to deal in milk and other dairy products. The mere establishment of standards and the passage of new ordinances will not solve the milk problem; there must be adequate inspection so that enforcement may be insisted on.

The work of the Health department on milk control is carried on by four milk inspectors, who are under the city chemist. The latter devotes only a small part of his time to milk work. Although paid out of the Health department appropriation, he has to act as industrial chemist to other departments, and analyze gas, coal, and cement. Two of the milk inspectors are called country inspectors. As a matter of fact these two inspectors devote only a part of their time to country inspection, most of their work being done in the city.

There is no question but that the present inspectors are very efficient in their work; they are all actively interested in it; and are by no means merely holding down their jobs; but it is manifestly impossible for these four men to inspect 1,900 dairy farms, 188 milk depots, 1,150 stores, railroad depots, and wagons, and to collect samples and analyze them themselves.

Chart I shows the present organization of the Health department with respect to milk, meat, and other food inspection.

Chart II shows the proposed reorganization of the work of the Health department as to food inspection.

It will be noticed that under this proposed reorganization there would be a chief of the entire division, and under him three sub-divisions, (1) Dairy Products, (2) Meat and Other Foods, (3) Food Laboratories. Such a method of organization has been adopted in many cities. It is considered better to have all those branches of the Health department dealing with foods of any kind under a single division. This is particularly necessary for the food laboratories. For particulars reference is made to the report on the reorganization of the Health department.

Chart I. Present Organization.

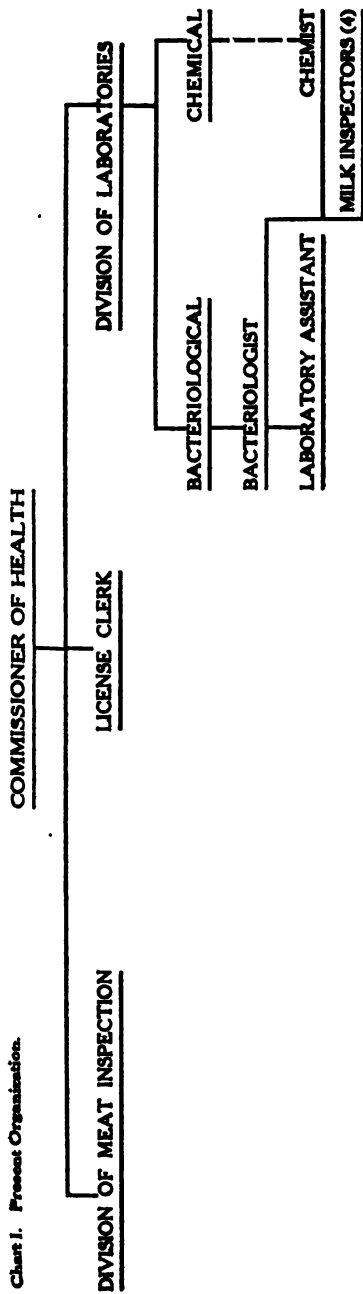
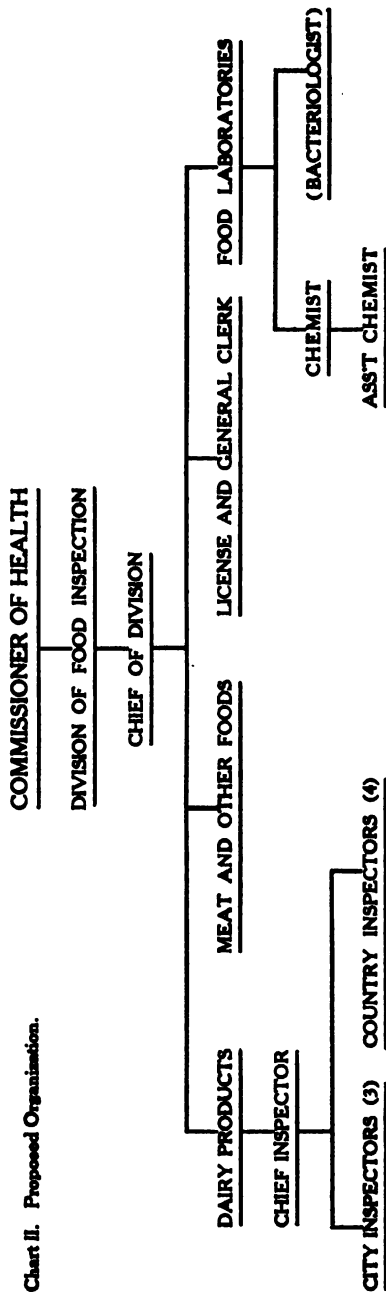


Chart II. Proposed Organization.



RECOMMENDATIONS

As a result of this study of the milk supply in Milwaukee and the methods used by the Health Department for its control, the following recommendations are made:

1. It is recommended that the work of the milk inspection, carried on by the Health Department, be organized and placed together in a division to be known as the Division of Food Inspection.

It is recommended that a chief be placed in charge of this new division and that he have complete control of the work of the Health department done in connection with the control of the supply of milk, meat, and all other food products.

2. It is recommended that this new division be organized into three sub-divisions, (1) Dairy Products, (2) Meat and Poultry, and (3) Food Laboratories.

3. It is recommended that in addition to the inspectors now employed there be appointed three additional inspectors, making a total of seven inspectors. It is recommended that four of these inspectors be detailed to the inspection of the dairy farms supplying the city with milk and cream, and the inspection of all shipping stations. It is recommended that the three remaining inspectors be detailed to the inspection of milk depots, receiving stations, and to the collection of samples for bacteriological analysis. It is recommended that to the three new inspectors, an additional inspector be appointed, and that he be in charge of the time in the supervision of the work of the other inspectors.

4. It is recommended that a chemist and a bacteriologist be appointed, who shall perform respectively the chemical and bacteriological work of the division under the supervision of the chief inspector. Also that a clerk be appointed to do the keeping of proper records and the performance of the clerical work.

5. It is recommended that the chief of the Division of Food Inspection co-operate with the chief of the Department of Education and Publications to the end that all interested parties who handle milk and other

may be thoroughly educated to a realization of why clean milk is necessary, and how it must be produced, transported, and distributed. It is further recommended that active steps be taken to educate the public on the milk question, so that they may realize the importance of sanitary milk, demand such milk, and be willing to pay a fair price for it.

6. It is recommended that the Milk committee of the Child Welfare commission be asked to devise a plan for giving wide publicity to the results of inspection of dairy farms, milk depots and stores.

7. It is recommended that inasmuch as the solution of the milk problem is not merely sanitary but economic as well, and that much good would arise as the result of a careful study into the cost of milk production, transportation and distribution, that the Milk committee of the Child Welfare commission be asked to conduct such an investigation. It is recommended that special attention be paid to a study of the proper basis for the purchase of milk by city dealers from farmers. Most food stuffs are bought and sold on the basis of quality, while milk is largely purchased by quantity alone—dirty, thin milk costing the dealer the same as clean, rich milk. If the committee could devise a way by which dealers would pay for the milk bought from farmers on a basis of its chemical and sanitary quality, the solution of much of the difficulty of the milk problem would be in sight.

8. It is recommended that the present milk ordinances be thoroughly revised and modernized, and that the system of records now used in milk work by the Milwaukee Health department be altered to conform with the new ordinances. It is further recommended that particular attention be paid (1) to the regulations regarding the sanitary conditions under which milk and cream are produced, transported, handled, and distributed (including the methods of pasteurization) and (2) to the safeguarding of the milk supply from infection by specific disease germs on premises or among the employes of producers and handlers or among the families of such producers and handlers. It is recommended that the Milk committee of the Child Welfare commission assist the Health department in the drawing up of the new milk ordinances, so that the department may have the benefit of the advice of the committee.

APPENDIX A.
MAPS SHOWING THE SOURCES, AMOUNTS, AND
LINES OF TRANSPORTATION OF THE
MILWAUKEE MILK SUPPLY

The two maps appended have been prepared with a dual purpose, (1) to show the extent and complexity of Milwaukee's milk shed and the consequent need of a liberal inspectional staff, and (2) to aid in an economic study of the situation, which it is hoped will be undertaken at an early date by the Milk committee of the Child Welfare commission.

Map I shows the amount, source, and lines of entry of all milk brought into the city by wholesale wagons and retailing farmers. The small amount of cream which enters the city in the same manner is likewise here shown.

Map II gives similar information for milk entering by way of the two steam railroads and by the Milwaukee Northern Electric line. These two maps taken together give a good picture of the entire milk shed of the city.

A brief inspection of Map I is necessary to demonstrate the extreme complexity of the problem,—the number of farms, the distances the milk must come by wagon, the ample opportunity for contamination and infection through careless handling, the difficulty of preventing the heating of milk in transit with the resulting deterioration in quality,—these and many other facts are at once apparent and serve to emphasize the magnitude of the problem with which the Health department must grapple.

These conclusions, furthermore, coincide with the results of the investigations recorded in the body of this report, and with them form a powerful argument for an increased inspectional and laboratory staff.

While the railroad milk is not as a rule so long in transit as that brought by wagons, it is subject to other and equally bad conditions, which result in its arrival in the city in about as objectionable a condition.

The following table is compiled from Map I and shows (1) the number of farmers who send their milk to the city by wholesale wagons for distribution by city dealers, and (2) the number of farmers who retail directly the milk produced on their farms. This table also affords a classification of farmers according to the number of cans of milk they produce.

APPENDIX B.

At a meeting of the Milk committee of the Child Welfare commission on December 7, 1911, the following resolutions respecting the foregoing report were adopted:

WHEREAS, a pure milk supply is of prime importance to the health and lives of babies and adult citizens in Milwaukee, and

WHEREAS, the protection of the public health demands adequate inspection of all dairy farms under the auspices of the Milwaukee Health department, and

WHEREAS, the funds of the Health department at present are not sufficient to enable it to employ an adequate number of inspectors,

NOW THEREFORE BE IT RESOLVED, that the Milwaukee Milk committee urges the appropriation by the Common Council of a sum of money sufficient to enable the Milwaukee Health department to maintain, during the coming year, a force of seven milk inspectors with a chief inspector in charge, and a bacteriologist and chemist to give their entire time to milk work and a clerk to attend to the records of the office. .

AND BE IT FURTHER RESOLVED, that a committee be appointed to urge the appropriation of this money upon the Mayor, the Board of Estimates and the Common Council.

WHEREAS, a report on the milk situation in Milwaukee has been prepared by Professor Selskar M. Gunn for the Bureau of Economy and Efficiency, in which a careful survey of the local milk situation has been made and recommendations proposed for improving the supply, and

WHEREAS, this report has been carefully read and edited by the Milwaukee Milk committee with the approval of Professor Gunn and the Bureau of Economy and Efficiency,

NOW THEREFORE BE IT RESOLVED, that the Milwaukee Milk committee heartily endorse this report and the recommendations appended thereto, and

BE IT FURTHER RESOLVED, that the Milwaukee Milk committee urge the immediate printing of this report in order that the facts presented by Professor Gunn and the recommendations which he has made, may be given wide publicity.

**CLASSIFICATION OF MILK PRODUCERS WHO SHIP BY WAGON, &
THE AMOUNT PRODUCED.**

Ship by Wholesale Wagon.			Retail from Own Wagon.		
Amount Produced Daily (Cans).	Number of Farms.	Total Amount Produced (Cans).	Amount Produced Daily (Cans).	Number of Farms.	Total Amount Produced (Cans).
$\frac{1}{2}$	32	16	$\frac{1}{2}$	0	
1	203	203	1	1	
$1\frac{1}{2}$	73	$109\frac{1}{2}$	$1\frac{1}{2}$	0	
2	257	514	2	6	12
$2\frac{1}{2}$	21	$52\frac{1}{2}$	$2\frac{1}{2}$	3	7
3	156	468	3	3	9
$3\frac{1}{2}$	3	$10\frac{1}{2}$	$3\frac{1}{2}$	0	0
4	51	204	4	8	32
$4\frac{1}{2}$	1	$4\frac{1}{2}$	$4\frac{1}{2}$	2	9
5	34	170	5	2	10
$5\frac{1}{2}$	1	$5\frac{1}{2}$	$5\frac{1}{2}$	1	$5\frac{1}{2}$
6	12	72	6	8	48
7	2	14	7	0	0
8	0	0	8	7	56
9	1	9	9	3	27
10	1	10	10	1	10
Totals ...	848	$1,862\frac{1}{2}$	Totals ...	45	227

Total number of farms shipping by wagon..... 893

Total number of cans of milk produced daily by these farms $2,089\frac{1}{2}$

REF-5171

cygon

SHOWING
Y SHIPMENT - MILK
ELWALKER DURING
AL SEASON

into Unit of one
alien Can of Milk

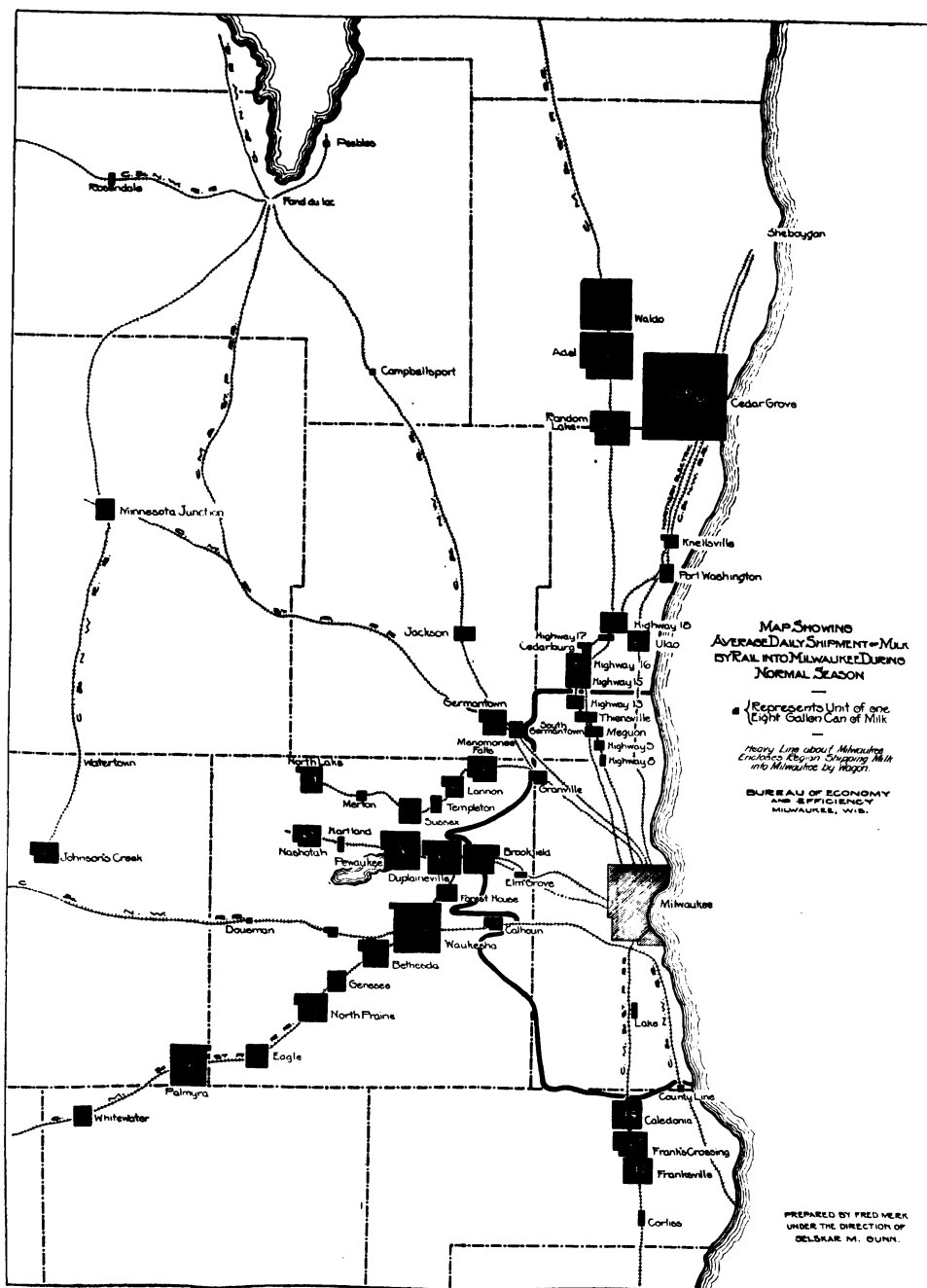
about Milwaukee
6 in Shipping Milk
Hoe by Hagen

3 OF ECONOMY
EFFICIENCY
HUES, WIS.

PAID BY FRED WERK
IN THE DIRECTION OF
LEKAR M. GUNN

UNIVERSITY OF MICHIGAN LIBRARIES





MAP II.



APPROVAL BY THE MILK COMMITTEE

The report on the milk situation in Milwaukee, herewith presented, has been carefully read and edited by the undersigned committee. In some instances changes in the original manuscript were suggested to the author and accepted by him.

We heartily endorse the report and the recommendations appended thereto and we urge the Mayor and the Common Council to see that the provisions suggested, for bettering the local milk supply, are carried out.

We believe that such action will greatly improve the quality of the milk supply, without any appreciable and permanent increase in the cost of milk to the consumer.

MILWAUKEE MILK COMMITTEE of the CHILD WELFARE COMMISSION

Chairman—

Prof. H. L. Russel
Dean of the College of Agriculture,
The University of Wisconsin

Vice-Chairman—

Wilbur C. Phillips
Secretary of the Child Welfare
commission

Secretary—

Dr. W. T. McNaughton
Secretary of the Milk Commission
of the Milwaukee County Medical
society

Mr. John LeFeber
President of the Gridley Dairy
Company

Mr. G. H. Yahnke
President of the Milwaukee Retail
Milk Dealers association

Mr. Chas. J. Steffins

Chief Milk Inspector, Milwaukee
Health department

Mr. Julian Ries

Secretary Milwaukee Milk and
Cream Shippers association

Prof. Henry C. Taylor

of the Department of Agriculture
Economics of The University of
Wisconsin

Mr. W. D. Carrick

General Baggage Agent, C., M. &
St. P. Ry.

Dr. John M. Beffel

Chairman, Milwaukee Child Wel-
fare commission

Mr. John Quincy Adams

Secretary Waukesha Dairymen's
association

UNIVERSITY OF MICHIGAN LIBRARIES

ECONOMY AND EFFICIENCY IN HEALTH ADMINISTRATION WORK

BY SELSKAR M. GUNN¹

Assistant Professor of Sanitary Biology and Public Health, Massachusetts Institute of Technology

ANY estimate of what constitutes economy and efficiency in health administration work cannot be regarded as satisfactory until the true functions of a health department have been properly defined. Such an understanding has not yet been attained, although the progress of sanitation in the last few years, resulting largely from the wonderful discoveries of bacteriology and the remarkable achievements of epidemiology, is gradually bringing a truer conception of the nature of those conditions which have not imaginary, but real health significance. A study of the annual reports of various health departments of this country reveals great variation, both in the objects pursued and in the detailed methods of attack.

Health authorities are being relieved gradually of the burdens of garbage and refuse collection and disposal, plumbing inspection, poor relief, and general hospital maintenance—matters of slight if any health significance. Consequently they are becoming more and more able to devote their whole time and energy to questions of real sanitary import, to the solving of problems which will actually result in the decrease of preventable sickness and in conserving human life and happiness. Again, it is generally conceded that at the present time health departments are usually inadequately financed. New funds are not granted for the furtherance of the work of the department, or if so, to only a limited extent. It is doubtful however, if the funds now actually at the disposal of the health authorities are being spent with *real* economy.

One of the chief causes of inefficiency and lack of true economy is to be found in the lack of proper knowledge as to the comparative importance of the various branches of work which may be pursued. A health commissioner is confronted with the question of what he ought to do to improve the sanitary status of his community. He has limited funds, and consequently cannot do all that he might wish. "Shall I make a special effort to curb tuberculosis, or devote my resources to improving the milk supply?" "Should meat and food inspection be developed before factory inspection?" Questions similar to these are constantly confronting every modern sanitarian in charge of a city health department, and the decisions that have to

¹ Selskar M. Gunn is Assistant Professor of Sanitary Biology and Public Health in the Massachusetts Institute of Technology. Formerly he was bacteriologist to the Massachusetts State Board of Health and Health Officer at Orange, N. J.

be made are not always easy or evident. However, it is only by developing such a sense of proportion that efficient administration can be obtained.

It is natural that health department organization should be far from perfect in most places. Their growth has often been unplanned, and the lack of knowledge in the past has largely prevented an orderly and scientific development. What might have been considered good organization twenty years ago would not be able to stand criticism in the light of modern discovery. We find at the present time that certain lines of activity receive far more attention than their actual importance would warrant. Excessive emphasis on meat and food inspection, and an accompanying neglect of milk supply supervision is a good example of this. The particular hobby of a health commissioner may lead to an unbalanced state of affairs, and is to be particularly guarded against. Again, the special prominence of some problem may lead the health officer to undertake work out of all proportion to the actual needs, and to the detriment of some other part of the service.

An interesting example of the great variation in the activity of health authorities with regard to work of the same character has recently come to my attention and will bear repetition here. The number of samples of milk and cream examined chemically in twenty-seven large cities of the United States varied from 4 to 344 per 10,000 of population, and the number of samples of milk tested bacteriologically in twenty-four of these cities varied from 0.6 to 288 per 10,000 population (these figures are for the years 1909 and 1910). While it is improbable that a standard number of analyses based on the population could be set, it is not unreasonable to maintain that these figures show that the health departments of some cities are devoting too much attention to this work and are allowing other lines of work to be neglected, while other cities are neglecting this work although they may be overemphasizing in some other direction. It certainly seems that those cities which are making so many chemical analyses are really going to excess in this particular, and that no added benefit in the form of a purer milk is being obtained for the city on account of this *unusual* activity. In one of the large cities which analyzes a great number of samples, the dairy farm inspection work of the department is practically *nil*, the inspectors having to spend so large a part of their time in the laboratory testing samples. The law of diminishing returns is a real factor in inspection work.

If we could really get at the relative importance of all the activities of a health department, we would be in a position to apportion the necessary funds in a scientific manner, giving due weight to each line of work.

The death rate of a city cannot be used as a measure of the efficiency of the health authorities. The fallacy of this method of determining the health status of a community has been conclusively demonstrated. Most careful studies of vital statistics are necessary and the good derived from some lines of endeavor cannot be demonstrated by any statistical methods

yet devised. The remarkable statements of some health officers concerning the health of their city would be amusing if they were not so serious as indicating ignorance on the part of these most important city officials.

Apparent economy may be attained by an untrained man, but in most cases true economy, combined with efficiency, cannot be had unless the health administration is in the hands of an individual thoroughly trained in the sanitary arts. It cannot be expected that any one who has not received special training, or who has had merely the few hours of hygiene allotted to the subject in a medical school curriculum, is a proper person to be put in charge of the public health activities of a community. The first essential for any city which is honestly seeking to maintain a health department of real value is to secure the services of a trained sanitarian. There is no alternative in this matter. For small communities which are unable to pay for the services of such an individual, it has been suggested that neighboring communities may combine, and so secure the services of an efficient man who shall be the executive for all.

A comparison of the requirements for employment in public health service in this country with those of England, Germany, and other European countries, reveals to us a quite unsatisfactory condition. In the foreign countries special evidence of fitness is essential. New Jersey, in the past few years, has required all persons who desire to enter public health service anywhere in the State to pass an examination, and to obtain a license. By this means many who are unfitted by lack of knowledge and training have been excluded from the service. Other States might well copy this progressive step. Too long have we played with the public health. It is a disgrace that severe epidemics are necessary to bring home the lessons of inefficient service. Nor does the necessity for trained officials end with the appointment of a health officer or commissioner. His subordinates should likewise be subjected to suitable examination. The growth of the civil service is a step in the right direction.

Among the common methods used by some health officers to combat insanitary evils is what I shall term, for want of a better word, the "outburst" method. I refer to transitory outbursts of activity directed at some particular business or condition which is supposed to have a bearing on the public health. Sometimes the bakers or ice cream dealers are subjected to a sudden and severe examination as to the sanitary conditions of their places of business, or maybe the fly nuisance is selected for a special campaign of theoretical extermination. While this method of occasional activity is sometimes the only available one for an under-manned department, and occasional inspection and sampling are better than none at all, yet I venture to remark that eminently better results could be obtained by regular and reasonable inspection.

It should always be borne in mind that the strength of inspection lies in frequent *reinspection*. Furthermore, the persons concerned prefer a regular inspection and certification. What health officers need is the coöperation of the public, and particularly of those engaged in industries or affairs which have a bearing on the public health. The educational value of frequent and friendly inspection needs no special argument to any who have been working on the problem of dairy farm inspection.

Real efficiency naturally incorporates in it economy. As has been pointed out by the Bureau of Municipal Research of New York City the question "whether administration has been economical or wasteful can be determined only by contrasting cost with service results." The investigators of this bureau have emphasized the proper recording of service results, and especially at times when the budget is being considered.

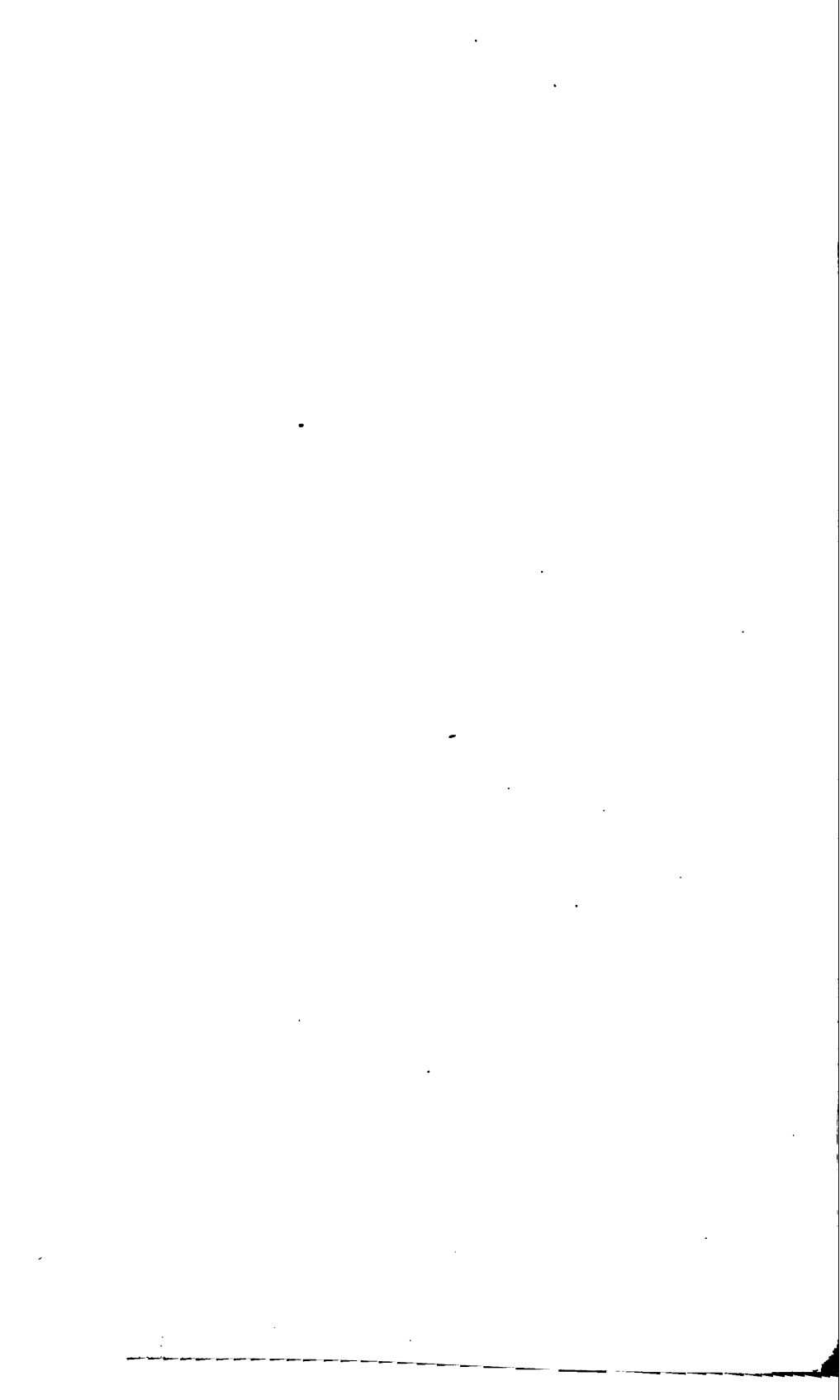
While it is true that it is difficult, and at times impossible, for a health department to demonstrate by means of figures the actual beneficial results of various of its activities on account of the complexity and diversity of conditions which may produce a particular disease, yet in certain lines it is eminently practical. We can see it in this city of Richmond in the reduction of typhoid fever, and in the improvement of the milk supply. The results of efficient service are demonstrated in the annual reports of the chief health officer, Dr. E. C. Levy, whose brilliant work has attracted the attention of all progressive sanitarians in this country. Methods similar to those used here should be employed elsewhere. They are essential for scientific budget making and should be a great aid in asking the city fathers for more money. Even at the best it takes time to get the needed appropriation, but this time may be considerably shortened by using modern methods to demonstrate the needs.

Accounting methods of health departments as evidenced by the financial statements contained in their annual reports are in need of some standardization if proper use is to be made of them. It is almost impossible for cities to compare their expenses with other similar communities. The Massachusetts Association of Boards of Health some months ago appointed a committee to draw up an outline of a form for use by the local city boards in their annual reports. The form of the financial statement is being carefully considered by this committee as an important part of its work.

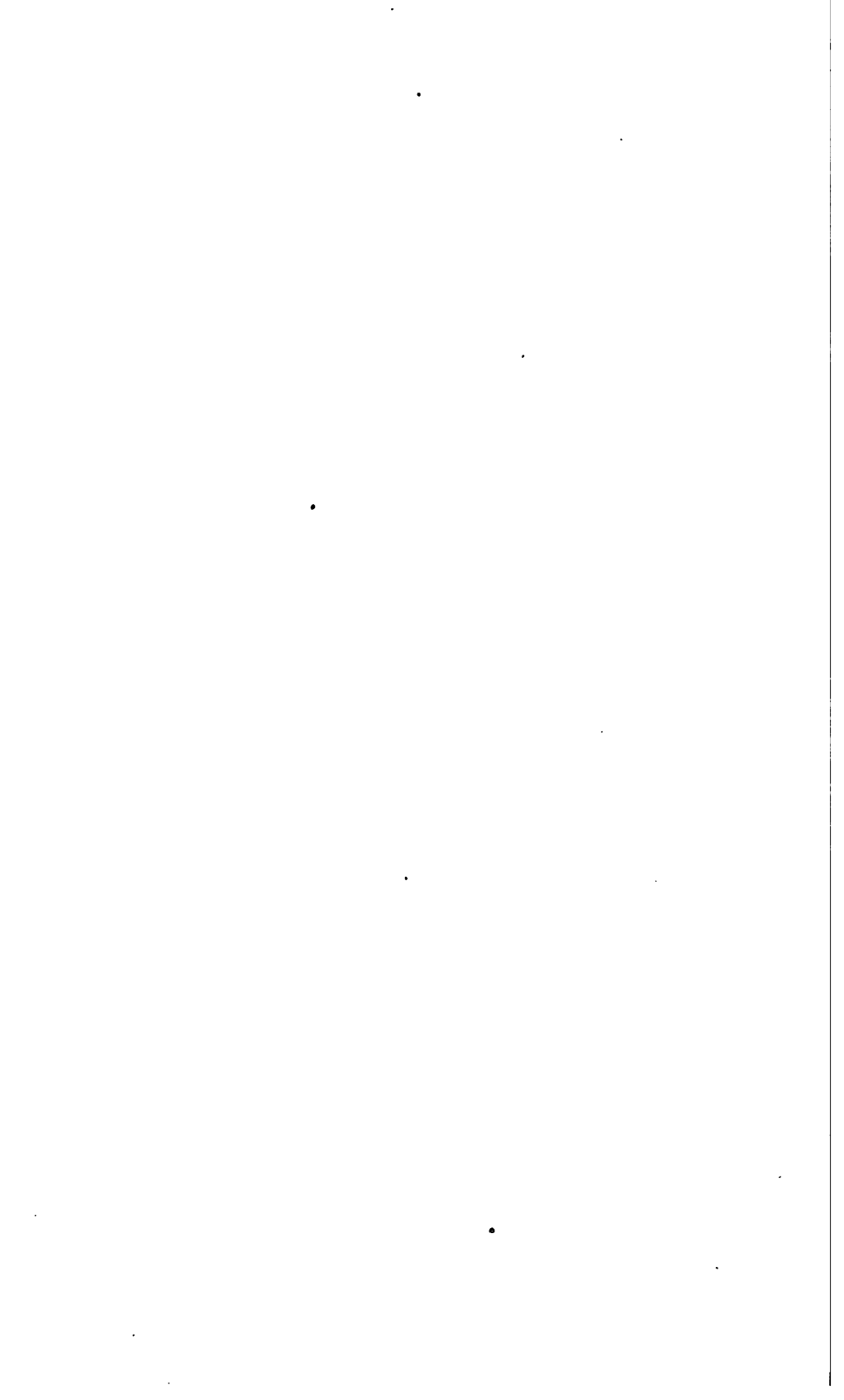
In a number of cities bureaus of municipal research are in operation, and are doing constructive work in reorganizing the activities and accounting methods of the health departments. This should have a very beneficial effect if carried on with the proper coöperative spirit, and should assist materially in the preparation of a sensible and clear budget that will interest the citizens and win their support.

In conclusion, it seems to me that in order that we may have health departments both economical and efficient, we must free them from poli-

tics with its accompanying uncertainties and strife, and place them in the hands of trained sanitarians who shall understand the relative importance of the different lines of endeavor and who will then be able to disburse an adequate appropriation in such manner that the community will receive the maximum protection at the lowest possible cost.







MODERN BOARD OF HEALTH METHODS IN SMALL CITIES.

By SELSKAR M. GUNN,
Massachusetts Institute of Technology, Boston.

As the time at my disposal is insufficient for a discussion of all the problems that confront the Boards of Health of small cities, I shall content myself with some remarks on certain important phases of the work.

It is rather difficult to define what is meant by a small city, but, for the purpose of this paper, I am going to consider as such, those communities with a population of from about ten to fifty thousand. It was my good fortune to serve as health officer in a city with a population of approximately 27,000 for nearly two and a half years, and I hope that some of my experiences and reflections may be of interest and value.

The history of the subject has demonstrated that most of the real advances in sanitary science and practice have arisen through the needs of large cities. In great cities, the magnitude of the insanitary conditions, combined with the immense amount of preventable sickness and loss of life, have commanded the attention of health authorities and have given rise to the inauguration of steps to attempt to offset the evil conditions of environment, or the serious results of ignorance, which have largely caused these dire results. The smaller cities in many parts of the country have only recently commenced to arouse themselves from their lethargy and to realize that the problems of the large cities are theirs also, though on a reduced scale. Many small cities, unfortunately, have not yet awakened from their sleep, though I think we may take pride in saying, that, in general, the small cities of this commonwealth cannot be truthfully included in this group.

It might seem unnecessary to state that the first essential for a Board of Health of any community is to have sanitary rules, which are up-to-date, but yet within the legal limitations. We oftentimes would like to adopt new rules, but we must not let our enthusiasm carry us to the point of passing regulations which we cannot legally enforce. Many health departments do some of their work on "bluff." It is a poor policy in the long run, even if it may at times bring results.

The second essential is, of course, to have adequate means of enforcing the health code. This necessitates, first, a staff of trained workers who should be adequately recompensed; second, the maintenance of a suitable office for the proper keeping of records and where someone can be found

at reasonable hours to answer questions, issue permits and respond to emergency calls; and, finally, the necessary equipment of disinfecting apparatus, sample cases, and the general apparatus for chemical and bacteriological analyses. Too frequently we find the health department—the most important office in the city—housed in a miserable room and presenting anything but the appearance of a modern city office.

Modern practice calls for the care of all records of vital statistics to be in the hands of the health department. This provision is essential as far as records of deaths and births are concerned; and perhaps the time will come when marriage licenses and certificates will also be generally looked after by the Board of Health. The modern practice, imperfect at the present time where in force, of demanding certificates of health from prospective brides and grooms, makes the health department the natural place for the issuing of licenses and the filing of certificates.

Vital statistics are recognized as being a valuable aid to sanitary science. If scientifically applied and interpreted they can be used as an instrument for measuring the sanitary status of a community, and they can be made to point out the weak spots and thus to indicate where special efforts should be directed. They can be used to measure improvements in the health of a community by indicating decreases in the number of deaths or cases of preventable sickness. We must always remember, however, that if they are inaccurately and unscientifically used they may be literally worse than useless. A campaign against infant mortality, for example, would be lacking in its greatest aid if the statistics of infant births and deaths were not available and made use of. It is a surprising fact that many boards of health of small cities do not control these important records, which they naturally should do.

The whole problem of nuisances seems to call for some comment on account of the attention that is given to them by health departments. It is perhaps hard to imagine a condition when nuisances shall no longer be dealt with by boards of health. Sanitarians are realizing more keenly every day that the vast majority of nuisances that take up so much time do not affect the public health, or, if so, in an inappreciable manner. This is particularly true in those small cities which are fortunate in having a good water supply and sewerage system, thus obviating the privy, the leaky cesspool, and the resulting polluted wells, which are, of course, nuisances of real sanitary import.

Nuisance work is largely police work, and, in my opinion, should be performed by individuals primarily connected with the police department, so that the health officer and his assistants may be able to devote their time to real questions affecting the health of the city, and not to the

inspection of dumps, ash heaps, dirty cellars, weeds, noisy phonographs, cackling hens, and the like. The modern trend is to make the plumbing inspector responsible to the city engineer, and this is as it should be. Perhaps we may yet see the nuisance inspectors put under the city police department and granted the full police powers so often lacking to the sanitary inspector, and, therefore, there may be greater efficiency in doing away with conditions that are distinctly objectionable but not necessarily unhealthful.

A few words with regard to modern practice in combating tuberculosis. It is becoming recognized more generally that the most important factor in helping to decrease this disease is the segregation of the patients. We must have better facilities for the hospitalization of our consumptives, particularly for the advanced cases, which too frequently are neglected in our enthusiasm and desire to cure the incipient cases. We simply must remove the advanced cases to a safe place, if we are going to cut down the incipient cases. We need greater authority to deal with the careless consumptive who jeopardizes the health and lives of those living near him.

I note in some board of health reports of this state, comments on the difficulty of obtaining reports of cases of this disease. My own experience in Orange, New Jersey, may be of interest in this matter. The Board of Health of that city in 1905 placed tuberculosis on the list of reportable diseases. In 1906, thirty-eight cases were reported and seventy-two deaths; in 1907, forty-one cases and sixty-eight deaths. On my assuming the health officership in March, 1908, I noticed the great discrepancy between the number of cases reported and the number of deaths registered. I sent out a courteous appeal to the physicians and made a point of following up all tuberculosis deaths that had not been reported as cases previous to their death, in order to find out the reason for the neglect, and I was able in that year to increase the number of cases reported to 116, and in 1909, to 127. It is now a very rare occurrence to receive a death certificate with tuberculosis given as the cause of death, where the case is not already on file in the office and the circumstances of the case known. We well know that one of the great difficulties in the tuberculosis problem lies in the fact that it is a hard task for a board of health with limited help to follow up the cases and keep track of them as they move from one part of the city to another. I made an arrangement with the local Anti-tuberculosis League to permit the board of health to appoint their visiting nurse as a sanitary inspector, her salary being paid by the League. This gave her the necessary authority to visit all cases which we considered it necessary to watch and made her an important figure, on account of her official badge, particularly in the eyes of the foreign

element, who were thus more apt to do what she told them. A tactful, gentle woman can frequently be of great service in persuading dangerous advanced cases to follow out directions in the home that will tend to minimize the dangers to those living in the same house or tenement. Not infrequently she can induce cases to go voluntarily to hospitals where they can be absolutely controlled. Incipient cases can likewise be urged to go to sanatoria, and day camps; and, not infrequently, the nurse can find other cases, perhaps in the children, and get them to go to a dispensary or elsewhere, for treatment. Finally she can see that a proper diet is obtained, where poverty prevents, by bringing the case to the notice of the diet kitchen, milk depot, or other private social agency in the community which may be doing such philanthropic work. Many of these organizations are not doing the effective work that they are capable of, because they are not in a position to discover the cases which they really should be assisting. They have oftentimes to take the cases as they come, irrespective of the real need, and so many who most need help are never reached.

All of this emphasizes the important fact that in small cities, the health department should co-operate in every way possible with all the private social agencies that are at work in the city. These agencies are not infrequently doing work that properly should be done by the health department, but which, through the parsimony or false economy of the city fathers, cannot be undertaken at the present time. Anti-tuberculosis leagues and milk depots are examples of this.

A sanitary inspector, if he is wide awake, will discover cases of destitution and distress which, although out of his province, should be referred to the local Bureau of Associated Charities for assistance. My own experience has shown this to be the case on many occasions. The visitors of the charity organization, too, find conditions that come within the province of the health department. Under such circumstances, a mutual feeling of good-will will be an important factor in efficiency. Too frequently we find the health department at loggerheads with the local private social agencies, or *vice versa*. There may be good reasons on occasion, but if a proper spirit of harmony exists, the health department will find valuable coadjutors in these organizations who may be of great value and influence, when it comes to questions of getting the proper appropriation for the board of health.

There is one subject which is a very important factor in health conditions that I fear is not getting the attention that it deserves in small cities. I refer to the housing problem. Many of our small cities at the present time have bad housing conditions—not only bad occupancy but also

bad construction. The great problem is perhaps not so much the eradication of existing insanitary conditions, necessary as this is, but the enactment of proper legislation which will prevent the erection of buildings that will be the despair of succeeding generations of health officers. It may be more dramatic to carry on a vigorous campaign against existing bad housing conditions than to advocate legislation to arrest this growing evil, but the latter method is really truer prophylactic work and worthy of the attention of boards of health. It seems to me that the time is ripe for concerted action, in order to obtain state legislation that will make it impossible for small cities to have overbuilt and insanitary areas of dwellings erected within their limits, and I offer this suggestion for careful consideration.

Time does not permit my referring in detail to modern methods of safeguarding the food and milk supply. The boards of health of this state, as evidenced by their reports, are, as a rule, making headway with these important problems.

Score cards for dairies and milk depots are being used more extensively from year to year, and, despite criticisms, they are, in my opinion, useful agents in bringing about improvements. It is to be hoped that a card may soon be available that will be sufficiently satisfactory to be generally adopted. At the present time there are various cards in use, and it is difficult, if not impossible, to compare the results of scoring in one city with those of another. Score cards are being used in a few places for stores, butcher shops, groceries, and vegetable stores—where all kinds of food are sold.

An excellent scheme is in use in a very few cities where inspection cards are given to all inspected stores in which the sanitary conditions are up to the standards of the board of health. I am told that it is a great incentive to stores that fall below this standard to improve, so that they can pass the inspection satisfactorily, and thus be able to display their cards. Constant re-inspection is, of course, essential in such a scheme. Barber shops and laundries can also be treated in the same manner.

I should like to say a few words with regard to the subject of annual reports of the boards of health of small cities. Last summer Mr. Maurice Scharff, of the Institute of Technology, at my suggestion sent out a circular letter to the boards of health of all cities whose population was estimated by the Census Bureau in 1908 as between twenty and fifty thousand, asking them to send him a copy of their 1909 report. He sent out one hundred and seventy-five letters and received seventy-seven replies—ninety-eight making no reply. Thirty-nine of the replies were in the form of an annual

report; three sent monthly reports; and ten sent letters to say that the 1909 report had not yet been printed (Aug. 1, 1910). Twenty-five wrote that they issued no report.

Mr. Scharff kindly turned these reports over to me, and I have obtained others independently, so that I have had an opportunity to look over 56 annual reports. Twenty-five are reports of small cities in Massachusetts, and it is easily seen that the Massachusetts reports are on the average more satisfactory than the reports of less enlightened cities in other states.

The value of an annual report is readily seen. The preparation of it is a good thing for the health officer. He has to stop and go back over the year and see what he has done to improve the sanitary condition of his city, and the mere fact that his work has to be published, and the report is to be circulated in the city, is an added incentive to him to make a good showing.

The wide divergence of method in drawing up these fifty-six reports examined has appealed to me. There is a great lack of uniformity—a very desirable quality—and in the majority of these reports, little evidence of any general plan. We should recognize that the reports are not merely for the information and use of the city in which they are issued. A good report has a field of greater usefulness. It enables others to see what methods we use and the results that we obtain, and we too can secure benefit by the examples of others as shown in these reports. We do not pay enough attention to the reports of other health officers and do not reap the benefit of their experiences or give them the benefit of our own.

You may be surprised to hear that in twenty-four of the fifty-six reports there is no hint made of the population; this omission was found in 13 out of twenty-five reports of Massachusetts cities. The methods of recording vital statistics are too numerous to mention. In the matter of mortality statistics, all kinds of classifications of deaths are used, the alphabetical method being the most common. It is a sad commentary on the intelligence of a registrar where we find phthisis and tuberculosis classified separately, phthisis in the "p's" and tuberculosis in the "t's". In one report there were recorded 6 deaths from phthisis and 37 from tuberculosis, and there were other examples of a similar nature, where certain diseases having several names were recorded as being apparently entirely separate and distinct.

The standard International Classification, or Bertillon System, was found in 10 out of the 56 reports examined. Modern methods demand that this classification shall be used in all instances.

Birth and infant mortality statistics were, with a very few exceptions, entirely omitted. The omission of birth records is of course easily under-

stood in southern and western cities, but not so easily in states where the birth returns are more or less complete and accurate. In only a few of the reports examined was I able to find statistics of the number of deaths under one year per 1000 births, or any other statistical information that would give a satisfactory measure of the infant mortality.

Financial statements of the expenses of the health departments were found in 32 instances. We must tell how much, or perhaps too often how little, we spend—other cities need this information. Salaries are usually lumped together. In sixteen instances the salaries of the various employees of the Board were given. They should always be given in detail. We should let the public know how little we pay our health officials.

Time will not permit my going into many other discrepancies. It seems to me that this whole matter is worthy of the attention of this Association. Might it not be a good plan to appoint a committee to consider the possibility of drawing up a standard form of report for boards of health of this state, giving all the necessary liberty for the discussion of purely local problems? There are certain facts and figures that should be given in all health reports.

It should be impossible to read, as in one report, that "out of 22 cases of contagious and infectious diseases reported there were only three deaths" and then be able to turn over two pages and find a table of the causes of death, with 4 deaths from diphtheria, 7 from typhoid fever, and 10 from pulmonary tuberculosis.

A final consideration, but an important one, is the vital question of education. Sanitary science has advanced markedly in the past few years; and to my mind one of the greatest advances consists in the recognition of the fact that it is PERSONS rather than THINGS that are the chief cause of the spread of infectious disease. Contact infection is coming to be considered the most important method of infection, and in order to combat infection from this source, we must have an increased knowledge of what clean living really means. This can be accomplished only by education, and progressive boards of health must constitute themselves into an unofficial educational body and use all means to spread the gospel of sanitary living. Those in actual charge of the education of our children must be made to realize the importance of the proper teaching of hygiene in the public, parochial and other private schools. The newspapers and the lecture platform can likewise be used to great advantage. We have a number of examples of such educational campaigns being carried on in different cities in the United States. In many places circulars on many topics of sanitary significance are also now issued and distributed broadcast.

The boards of health of the small cities of Massachusetts, in some respects, are already leading, but it is possible for them to make still greater advances. If we are agreed that we need better housing laws, better methods for combating tuberculosis and infant mortality; if we are agreed that uniform methods of recording our work and its results are to be desired; then we can work together to overcome the difficulties that beset our path. The task is a big one, but let us remember that it takes concerted and co-operative effort to move heavy obstacles. In this state, there is no better or more direct way of accomplishing these ends than through the efforts of this Association.

MODERN BOARD OF HEALTH METHODS IN A SMALL TOWN.

By C. K. BLANCHARD,

Agent of the Board of Health of Wellesley, Massachusetts.

The problems met by the Board of Health of Wellesley, a residential town of about 7,000 people, are probably similar to those which arise in many other small towns of the state. The Wellesley Board of Health is composed of three members, each of whom, except the secretary, who receives a nominal salary, serves for three years without compensation.

Prior to June, 1909, five men were employed on a part time schedule. The members of the Board themselves gave their spare time to abating nuisances and to performing other similar duties. This organization was unsatisfactory, because much of the work was naturally performed in a perfunctory manner, and the system lacked co-ordination and intelligent direction. In the spring of 1909, some change being imperative, as an experiment, I was employed to do all the work of the Board.

To provide the necessary headquarters and facilities for work, an office and laboratory were established in one of the town buildings, and the equipment for simple bacteriological and chemical work was purchased. A microscope, incubator, and sterilizer, for the bacteriological work, and a balance and centrifuge for milk testing, together with the necessary glassware and reagents, completed the laboratory. These, with the usual furniture for an office and meeting room, cost about \$300. The office is equipped with telephone service, and the various national and state health publications, as well as bulletins from cities in different parts of the country and from private sources, are kept on a reading table for convenient reference. The office is the central station from which physicians may obtain culture, sputum or blood outfits, vaccine, antitoxin, or silver nitrate solution at any hour of day or night. Opportunity is also afforded for incubating cultures at any time. The supplies mentioned may also be obtained at a sub-station in another part of the town.

The plan was to do the laboratory diagnoses for the local physicians for diphtheria, tuberculosis, typhoid fever, and malaria; to test milk for fats and solids, and, to some extent, make bacterial counts. This plan has been followed from the start, and, we believe, with satisfactory results.

Last year the following work was done at the laboratory:

Cultures from nose and throat.....	63
Sputum examinations.....	19
Widal tests.....	5
Blood examinations for malaria.....	4
Chemical milk tests.....	119
Bacterial counts for milk.....	5

The office hours of the agent, from 8:30 to 11 A. M., allow time for laboratory and office work, receipt of communications, and similar routine. The remainder of the morning and the whole afternoon are devoted to visiting quarantined premises, placarding and disinfecting for communicable diseases, inspection of plumbing, inspection of dairies, markets, etc., investigating complaints, or superintending the collection of garbage. As we have had very little trouble in securing reports of contagious diseases, except in cases of measles, it is seldom necessary to examine suspicious cases where no physician has been called. When necessary, investigation is made by one of the physicians on the Board of Health.

The present system has many advantages. The value of regular office hours and prompt attention to business is obvious. There is decided gain in the co-ordination of all parts of the work. The one who diagnoses a case of diphtheria also placards the house, gives directions for the quarantine of the patient and sees that they are carried out, examines the release culture, and, finally, disinfects the house and issues the permit for the child to return to school. Again, the collecting and testing of milk samples and the inspection of dairies is done by a man familiar with the conditions under which all the milk is produced, and personally acquainted with the producers themselves. The system also results in a marked saving of time by allowing the Board to devote its limited time to deciding important questions.

It is well understood that the great need of today in public health work is education. We cannot expect support from citizens who have little or no conception of what we are trying to do, nor can we hope to reduce greatly communicable diseases until the public have some intelligent idea of infecting organisms and means of guarding against them. For the purpose of spreading the knowledge of these subjects, we believe that a trained agent or health officer would be of great value to a small town. But the question may arise, "Why should not the physician of the Board attend to this?" Unless he is the only physician in the town, there would be serious objections to his visiting all contagious cases. It is hardly necessary to say that he must consider his own practice first and

use great discretion in his public service; whereas, a person having no practice to consider may act in each circumstance solely as the representative of the Board of Health.

With a person giving his whole time to the work, it is possible to do not only a greater amount of work, but also more varied kinds of work than could otherwise be done. For example, inspections of all kinds, frequent visits to quarantined premises, close watch of possible nuisances, general supervision of the sanitation of a town, could be cared for instead of carrying out merely the duties imposed by law or by clamorous public opinion.

There are, of course, disadvantages in this system. A man cannot be a specialist in all branches of Boards of Health work—in laboratory diagnosis and plumbing inspection, for instance, he will not have the skill or experience that is secured by employing different persons, each trained in his own department, and giving his whole attention to work of one kind. A decided disadvantage in the minds of some taxpayers would be any increase in expense. Unquestionably, if the whole time of a man capable of doing the diagnostic work and the chemical and bacteriological milk tests is to be secured, the cost will be greater than the appropriation made by some towns. In Wellesley, however, with the exception of the amount expended for laboratory equipment, the cost of the year's work in 1909 under the new system was approximately the same as if the old methods had been retained, or about \$1100. The figures for 1910, computed on the same basis, seem less favorable, being roughly \$1100, if the old system had been retained, as against \$1500, the actual cost. It should be remembered, however, that this comparison is not a just one, as a great deal of work was done that would not have been undertaken with the old methods and a smaller appropriation.

It is not my intention to suggest the system of administration just outlined as applicable to all small towns or even to all large ones. But there are doubtless many towns in the state where the system, with a few changes, could be used to advantage.

In conclusion, I should like to suggest a modification of this system, which seems practicable, and which, if adopted by the smaller towns, would increase the efficiency of health department work throughout the state, without calling for greatly increased appropriations. This could be accomplished, I believe, by the Boards of Health of two or three adjoining towns combining to secure the services of one or two trained men, who would carry on the work of the towns much as the agent does in Wellesley. Combinations of this kind are especially provided for in the laws relating to hospitals for contagious diseases and inspection of plumbing, and are in accord with the movement for efficiency everywhere.

Two men might be employed to advantage in such a system; one a bacteriologist and chemist, or a sanitary biologist, to direct all work, attend to office and laboratory duties, and take charge of the enforcement of quarantine, while the other would do the inspection work, investigate nuisances, collect milk samples, and perform similar duties. This would form an efficient administration, and would give excellent service at small expense for each town. Each district would have its laboratory where diagnostic and analytical work could be done quickly. At the same time each town would keep its individuality, have its own Board of Health, and conduct its affairs as now. Such a plan would be especially advantageous in a small town where the Selectmen are the Board of Health, or where the members have but little time to give to their duties.

This method would also perfect the organization of health work throughout the state. With the State Board of Health having general charge, with State Inspectors in charge of large districts, as at present, and sanitary biologists in charge of the actual work in the cities and from one to three or four adjoining towns, but working under the direction of the local Boards of Health, the organization for the care and control of communicable diseases, for securing clean milk, clean conditions under which food is handled and sold, and sanitary conditions throughout the state should be more complete, efficient, and practicable.

Natural Ice and the Public Health

AN ADDRESS

By DR. WILLIAM T. SEDGWICK

Professor of Biology and Lecturer on Sanitary Science and Public Health
Massachusetts Institute of Technology, Boston; Author of "Principles
of Sanitary Science and Public Health," etc.



The Natural Ice Association of America

116 Nassau Street

NEW YORK, N. Y.

Natural Ice and the Public Health

By W. T. Sedgwick, Ph.D., Sc.D.

*Professor of Biology and Lecturer on Sanitary Science and Public Health,
Massachusetts Institute of Technology, Boston. Author of
"Principles of Sanitary Science and Public Health," etc.*

THE art of refrigeration is very old, but scientific studies upon it probably date only from the time of Francis Bacon who, it is said, lost his life by a cold contracted while experimenting upon the keeping of poultry by snow. The popular use of ice for refrigeration purposes appears to have begun in the nineteenth century and to have grown up most rapidly in the northeastern United States which because of their tropical summers and polar winters require and can readily furnish an abundance of natural ice. The history of the exportation of ice from New England to foreign countries, including Great Britain and the West and East Indies, is one of the well-known romances of the industrial history of the nineteenth century.

It used to be urged, and sometimes is still, that the drinking of ice-water is a dangerous practice, the original theory being that a sudden chilling of the interior of the body by cold drinks must necessarily be harmful. More recently it has also been urged that the direct mingling of ice with drinking water introduces a previously unsuspected danger, namely that the ice may bring with it dangerous germs of infectious diseases; but in spite of all objections the use of ice-water has steadily increased and seems rapidly tending to become worldwide, for it has even extended to foreign countries, where it was once looked upon both with fear and contempt. For my own part I have no doubt that this extension is on the whole beneficent, for I am myself a thorough believer in the wholesomeness and wisdom of the general use of ice-water, especially in countries like some of the United States which have an almost tropical climate during a considerable part of the summer. That these also possess a winter climate which is nearly polar makes for them the supply of ice all the easier.

The principal physiological effect of ice-water is that of a powerful and, when one is habituated to it, a most agreeable stimulus; and I have never seen or heard of any good evidence that this stimulus was harmful. On the contrary I firmly believe that a more extensive use of ice-water as a satisfying yet harmless beverage and stimulant would go far to diminish in hot weather the demand for more harmful stimulants such as alcoholic drinks. I have myself seen in a barroom a patron, evidently

habituated to alcoholic drinks, instead of calling for something alcoholic pour out for himself on a hot day a glass of ice-water, with the remark "After all there is nothing in hot weather like a good drink of ice-water." This experience was to me not only an interesting physiological demonstration but also a broad hint as to the best and cheapest of temperance drinks. So fully am I persuaded as to the value and the harmlessness of the ice-water habit that I am quite ready to go on record as one of its ardent defenders, although I must hasten to add that, like many other good habits, this may lead to abuse. There is no earthly reason, for example, why when one goes to a hotel in the winter and sits down at a table in a restaurant he should find awaiting him a water glass crammed so full of ice that there is little or no room in it for water; or why the waiter, if the glass is only half-full of ice, should, before doing anything else, proceed to fill or overfill the glass with that useful material. To do this is both wasteful and an abuse of a good practice.

It is a noteworthy and significant fact that cracked ice is now frequently taken into the mouth and, as it were, eaten by many hospital patients, as well as by travelers on shipboard inclined to or recovering from seasickness. This appears to be done sometimes to reduce fever, sometimes to diminish disagreeable tastes in the mouth, and sometimes to supply an agreeable and harmless stimulant.

Ice is necessarily taken if at all as a raw food, that is to say, it must always be consumed uncooked. It is still one of the pleasantries of Sanitary Science to recommend to the unwary that ice should be boiled before it is taken.

But since the establishment of the germ theory of infectious disease, with its flowering in the wonderful era of the great pathological discoveries, that is to say since about 1885, raw and uncooked foods and drinks of all sorts have justly come under suspicion as possible vehicles of disease; and raw ice, like raw water, raw fruits, raw milk, raw oysters, and various other raw foodstuffs, has been suspected of conveying germs of disease and more especially those of typhoid fever.

About ten years ago I had occasion to consider very carefully the general subject of ice supply and the public health, and to prepare a careful digest of the evidence then available bearing upon the general subject of the transmission of disease germs through ice. My conclusions were published in 1902 as Chapter X of my "Principles of Sanitary Science and Public Health," and were entitled, "ON ICE AS A VEHICLE OF INFECTIOUS DISEASE. THE POLLUTION OF ICE. ICE SUPPLY AND THE PUBLIC HEALTH." The more important paragraphs of this chapter were entitled "Does Polluted Water Purify Itself in Freezing?" "Epidemics Attributed to Infected Ice," "Investigations of the Purity of Ice by Various Observers," and "Ice as a Vehicle of Disease." I have just read this chapter over again carefully, and I find that, even after the lapse of ten years or more, it represents quite accurately my

present ideas and opinions, and that I am entirely willing to re-affirm the conclusions brought together in the last paragraph (page 262), which reads as follows:

"Still, when all has been said that can be said against ice, as a vehicle of disease, and while it cannot be denied that ice may at any time under suitable conditions readily serve as such a vehicle, it nevertheless remains true that water certainly strongly tends to purify itself in freezing, and that no considerable amount of disease has ever been satisfactorily traced to ice either as source or vehicle. As a vehicle of disease, ice is plainly far less dangerous to the public health than is either water or milk."

As to the comparative unimportance of ice as a vehicle of disease I feel even more strongly than I did then, that ice supply, in comparison with water supply, milk supply, and oyster supply, is of only trifling importance. I am unable otherwise to interpret the significant fact that, while thousands of tons of ice have now for many years been annually consumed by all sorts and conditions of people, not a single epidemic of infectious disease has hitherto been satisfactorily fastened upon any ice supply.

As to the relative merits of natural and artificial ice there is a good deal to be said. In the northern portions of our country natural ice is often formed during extreme cold, and may be accordingly of superior hardness to ordinary artificial ice which is frozen at a higher temperature. Natural ice should therefore often last longer and be more economical. As to purity I may say this: If natural ice is cut from pure lakes and streams, with due sanitary precautions, there is no more reason why it should not be used for drinking purposes than there is why the water from which it is cut should not be so used. With artificial ice the same principles hold. If artificial ice is made with due sanitary precautions among the workmen employed, and from water which is fit to drink, there can be no possible objection to mingling it with drinking water. If, on the other hand, natural ice is taken from ponds and streams the water of which is impure, or is handled by dirty men in dirty ways; or if artificial ice is manufactured from impure water in dirty ways; then there appears to be some advantage on the part of the natural ice inasmuch as this has usually some opportunity to purify itself during the process of freezing, a fact of great sanitary importance, while artificial ice has no such opportunity. Natural ice generally and almost necessarily enjoys a further and considerable sanitary advantage in the beneficial effect of storage, during which process there is a marked tendency for any germs of disease which may be present at the start, to perish. Artificial ice, on the other hand, is seldom stored, but generally disposed of immediately after its manufacture.

As to the practice of putting ice directly into water or other drinks, such as iced tea, iced coffee, lemonade, and the like, the facts appear to be as follows: That whereas some risk is necessarily run by this introduction of a raw or uncooked food material, the danger is but trifling

in comparison with those to which we are exposed from many other sources, as for example in the use of raw milk. Moreover, the gain derived by the greater efficiency of ice-water as a harmless stimulant appears to me to outweigh on the whole the danger of any possible infection, and after weighing carefully the dangers there may be in the practice, I have never hitherto hesitated to have and to use abundantly in my own family ice-water and other cold drinks brought down to a low degree of temperature by the direct addition of considerable quantities of cracked ice generally derived from natural supplies.

The foregoing appears to me to be a general statement of the present state of our knowledge concerning ice supply and the public health. I have purposely avoided dealing with the bacteriology of ice, leaving that to my friend, one whom I am proud to call my former pupil, Professor Jordan, of the University of Chicago. I have also refrained from dealing with epidemics attributed to ice, or except in a most general way with the epidemiology of ice, because we are fortunate in having with us to-night Professor Hill, Chief of the Epidemiological Division of the State Board of Health of Minnesota, who has himself, like Professor Jordan, made many bacteriological examinations of ice, and who has dealt, and is constantly dealing, with epidemics which might be and doubtless sometimes are attributed to the use of natural or artificial ice.

But before I sit down, gentlemen, I want to say one more word. I should recommend to you that whenever the allegation is seriously made that your ice supplies or any ice supplies, natural or artificial—for you are all bound up together in this matter—artificial and natural ice—whenever any serious allegation is made concerning the sanitary quality of the ice which you may be selling or may be dealing in or may be knowing about, then you should be careful to run down that rumor to the very bottom; and in doing that you should be careful to have somebody do the work who knows what he is talking about. I have before me, for example, a clipping from the New York "Press" of November 5, 1910, which shows what the active reporter may do by way of looking over some vital statistics, and how he may unintentionally do injustice to an industry like that in which you and I are interested. Under the heading of "Typhoid Fever Traced to Ice," this energetic reporter proceeds:

"Health Commissioner Lederle yesterday gave out statistics concerning typhoid fever in parts of this city, as a result of investigation of cases in the Ninth and Nineteenth Wards.

"In the first-named ward the investigation covered a period of six weeks, beginning July 26, and the number of cases reported was eighty-eight. The normal average for the period in the district for five years from 1905 to 1909 was thirty-one. Of the cases investigated four were due to out-of-town infection. There were two cases each in six families and four of these were due to direct exposure.

"In the Nineteenth Ward the six-week period of investigation began on September 3, 1910. Fifty-seven families were infected and the normal average of cases for ten years was forty-five. The number of cases of out-of-town infection was seventeen. Cases due to impure water, four; artificial ice, nineteen; natural ice, fifteen; raw oysters, two."

Now I know Dr. Lederle well and I know that he is a careful scientific man, and unless he writes something himself saying that those nineteen cases were due to artificial ice or any other kind of ice, I for one respectfully doubt the truth of this statement. Coming down towards the end of the article, here is what we find:

"In the Nineteenth Ward a six-weeks' period of investigation began on September 3, 1910;"—which is the very time when we always have in all our large cities, and even the country, a good many cases of typhoid fever due to a great variety of things and not to be accounted for off-hand by a ready writer for the press or anybody else, but only to be accounted for very cautiously, after mature and thorough study, by people who know how to do the work, by people who have tried it and have been working in it, so that their conclusions may receive the weight to which they are justly entitled. But to continue:

"In the Nineteenth Ward a six-weeks' period of investigation began on September 3, 1910. Fifty-seven families were infected, and the normal average of cases for ten years was forty-five." Fifty-seven families, whereas the average number of cases for ten years was forty-five; but very likely in some of those years it was as high as fifty-seven. So that does not necessarily mean anything at all. "The number of cases of out-of-town infection (what is sometimes, I believe, wrongly but nevertheless very commonly called "vacation" typhoid—I won't go into that matter) was seventeen; cases due to impure water, four; artificial ice, nineteen; natural ice, fifteen; raw oysters, two."

Now, gentlemen, if any epidemiologist or sanitarian had carefully investigated those cases and had come to this conclusion his observations would be entitled to the utmost respect and weight. But if, as is likely in this case, the ordinary house inspectors had simply inquired, "What water do you use?" and had found that the water that they were using was perhaps not of the best, or had inquired, "What ice do you use?" and had found that some was artificial and some natural ice, and put that down; or had asked them, "Do you eat oysters raw, or do you not?" and found that two cases had eaten raw oysters, and had then jotted that down, that means nothing at all. It simply means that as far as this preliminary questioning went these were the answers obtained. There is no evidence in this clipping, very likely there is no evidence at all, that any of these cases were really due to impure water, artificial ice, natural ice or raw oysters. That is to say, you must doubt results of this kind, unless you know who they are who say that the thing was due to this or that and even then you must doubt them. We experts doubt one another and we have to be exceedingly skeptical in these matters, because it is no easy matter to run down an epidemic to its source.

I am trenching on the ground of my friend Dr. Hill, but I can tell you that we experts have hard work to be sure that we have got the right cause for a particular epidemic. It is one of the most difficult things in the world. It is detective work of the highest order. We have to be like Sherlock Holmes, accomplished in our profession, and we often conclude that we cannot ourselves determine just to what these various cases were due. We certainly do not reel things off in this free and easy way and I do not believe that Dr. Lederle ever did. I think it likely that the reporter or the house inspector simply put down the fact that these people did have natural ice or artificial ice or oysters or what not, and possibly in some cases impure water. It would be a most astonishing and remarkable fact if the difference between forty-five and fifty-seven cases were due to this great variety of things; and I mention this simply to ask you to doubt things of this kind when you read them; and what is more important, to follow them up and make the people who have made those statements show their hands and give their evidence. It is a question of evidence in most cases, it is not merely a question of opinion; or, if it is a question of opinion, then it must be only the highest experts whose opinion shall be received as valid.

This then is what I have to say, gentlemen; and in conclusion let me congratulate you upon dealing with a food product—for we must consider it as such—a food product which is of increasing usefulness in the world to-day in the preservation of the surplus food material of one time or season, so that it shall be available and useful at another time or season; which is useful too as a harmless and agreeable summer beverage and stimulant; and which, taken by and large, is one of the purest of the food materials of our time.



AN INVESTIGATION OF
HOUSING CONDITIONS
IN SALEM, MASS.

SELSKAR M. GUNN
SAMUEL M. SCHMIDT

Report to the Housing Committee
of the Associated Charities and to
the Committee on Nuisances of
the Civic League.

INTRODUCTION.

The duty of science is twofold, first to seek the truth ; second, having obtained truth to apply it towards the welfare of humanity. Sanitarians and other men of science cannot agree with the Malthusian doctrine which implies that crowding and unsanitary conditions in general must exist in order to save the people from a slow process of starvation which might be brought about by the over population of the world. On the other hand, sanitarians and scientific men believe that in order to save people from premature death and suffering we must make every effort to abolish crowding and unsanitary conditions, and that it is the duty of every individual to contribute his share towards obtaining the best sanitary conditions possible.

The question of housing of the poorer classes has of late received much attention in this country. This attention has, no doubt, been stimulated by the general tendency of the present age to lay great stress on the influence which environment exerts on the people. Mrs. Ellen H. Richards says, "Not through chance, but through increase of scientific knowledge ; not through compulsion, but through democratic idealism consciously working through common interests, will be brought about the creation of right conditions, the control of environment." (1) The house naturally plays a very important part as an environmental factor of the people, since it is there that the children develop and it is there that the adults are to secure rest after their hard day's labor. The importance attached to infant mortality makes the question of housing the more important, for the conditions of the home are of paramount importance to infants who are confined to the house practically all the time.

To have a clear view of the housing problem it is necessary to consider the factors contributing to the problem and their respective influence on it. There are practically two factors which have brought about the recognition of the problem. The first is the rapid growth of the urban population, occasioned by the development of manufacturing industries, by the growth of trading and by the increased facilities for transportation, which has forced people to mass themselves in convenient centres. This gave rise to the quantitative aspect of the problem ; an excessive demand for housing accommodation in these special centers took place. To keep up with the demand

and in the absence of any restraint, a great deal of over crowding of individuals inside the houses took place, and houses intended for one family were made each to accommodate several. This was the great opportunity for the "Jerry Builders", that is to say, men with no welfare at their hearts save their own pocket, and no special knowledge of the construction of dwellings save that possessed by the ordinary mason or carpenter. Such men, partly through their greediness and partly through their ignorance, supplied the excessive demand for housing accommodations by erecting large dwellings, utilizing every inch of available ground without any regard to space for sunlight or ventilation or any other sanitary conditions. Dwellings were literally piled one on top of another. Such briefly was the process by which the slums of our large cities have developed, and such *is* the process by which the slums are now being developed wherever the population is growing and no provisions are made for the prevention of the above conditions. The second factor, that on the side of Sanitary Science, Public Health, and Standards of Modern Civilization, gives rise to the qualitative aspect of the problem which is more important and of much wider application than the quantitative aspect arising from urban congestion. This is at once made obvious when we consider the great importance attached to rural housing in recent years. Mr. Dewsnup says, "It is not to be supposed that the villages and the rural areas are free from housing evils. Over-housing is not common, but over-crowding and insanitation may be more frequently met with than our ideals of country life would lead us to expect." (2) Although we may hope to solve the problem of quantity, the problem of quality will be with us all the time. Our standards of quality are continually changing, good housing of one period is condemned by another period. Very few old house which were considered excellent at the time they were built would satisfy modern sanitary standards. We are beginning to realize that even the poor are entitled to some of the comforts of life; and although modern sanitary science tells us that a little sewer gas is not dangerous to health and that back yards filled with old tin cans and other rubbish are not apt to spread disease, yet standards of modern civilization demand *decency*, and decency is not at all compatible with dirt and filth of any nature whether productive of disease or not. Human nature is imitative and the force of good or bad example catching. If we are to expect people to live decently we must provide them with decent surroundings. What is to encourage people to keep

clean when bathing facilities are denied to them? How are people to keep decent if they are forced to live in tenements where privacy is unobtainable?

Let us now consider more definitely the influence that bad housing has on health and morals of the inhabitants. No one can deny that a crowded, ill-ventilated, dark and dirty tenement is far from being an ideal resting place for a working man, tired from his day's labor. Let us consider the effect of dark tenements on the occupants. This can be done much better by considering the beneficial effects of sunshine. First we have the value of sunshine as a stimulant. The effects of sunshine on our nervous system are almost as telling as the effects of an alcoholic beverage; sunshine, however, is a natural stimulant and not at all injurious. Second, the germicidal quality of sunshine minimizes the chances of infection. Then again, sunshine discloses dirt and consequently cleanliness is encouraged. Sunshine reduces dampness and warms the tenement, thereby helping to maintain the vital resistance of the occupants. Is it then to be wondered at that the inhabitants of the dark and dingy tenements, lacking the natural stimulant "sunshine," should seek the unnatural stimulant "alcohol?" "The cheerless condition of the neglected tenement house," says Dr. Janes, "the devitalized condition of the atmosphere inhaled by its occupants have the effect to gradually enfeeble the vital powers and to create the desire for stimulants, which being indulged, deprives the family of a sufficient amount of proper food, and gradually paves the way to disease, intemperance and crime; the father of the family becoming dissatisfied with the cheerless condition of his home, spends his evenings elsewhere, probably at the saloon, to the neglect of his family, wasting the scanty earnings which are needed to supply the wife and children with the necessities of life, thus depriving them of the first conditions upon which they expect to acquire and enjoy a reasonable degree of health."

(3) The effects of over-crowding and bad ventilation can best be illustrated by the study of tables 1 and 2. The first table gives the different death rates from all causes and from phthisis among people living under crowded conditions, showing that the greater the percentage of people living under crowded conditions, the greater is the death rate. The second table compares the death rates from all causes, common infectious diseases, consumption, other lung diseases, and diarrhoea, of back-to-back houses where the ventilation

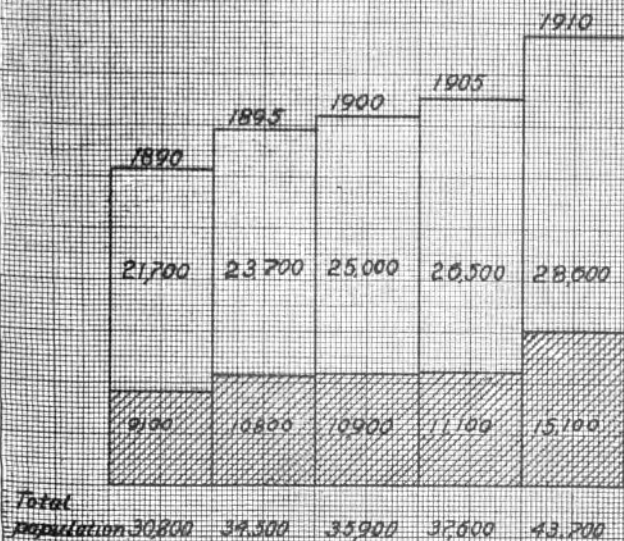
is very poor and of through houses where the ventilation is much better. After making a careful study of the death rates from various causes of people living in back-to-back houses, Dr. Darra Mair concludes, "On the whole it is reasonable to infer that even in good types of back-to-back houses, situated in healthy areas, the mortality from all causes is higher by 15 to 20 per cent. than in comparable good houses."

Any discussion of the Housing Problem is incomplete without considering the economic aspect of the subject, and in considering the economic side of the question it will be seen that it is intimately connected with the other factors of the problem. The problem of providing dwellings which shall come up to the standards of modern civilization and to the requirements of Sanitary Science, Public Health, and Decency, at a price within the reach of the poorer classes, is a most difficult one and can be solved only on economic lines if it is to be solved at all. The growth of cities, and the great land speculations going on in these cities, increases the price of land enormously; the requirements on the part of building laws, with a view to bettering the housing conditions, increases the cost of construction; the increases in land value and in construction cost advance the rent; high rents produce room crowding and poverty. Poverty is intimately associated with bad habits, with dirt, waste, idleness and vice. All these factors, economic and others, operate both as cause and effect. They cannot be separated in real life and are continually reacting upon each other in such a manner that it is impossible to arrive at their respective shares in producing existing evils. Another point to be borne in mind in considering the economic side of the question, is that model dwellings are bound to secure a great increase in the earning capacity of the working people living in them, for people living in model dwellings are less apt to lose wages by staying out of work on account of minor ailments such as cold, headaches, etc. Then again model dwellings by reducing the death rate of its inhabitants can save the community thousands of dollars. "The national annual unnecessary loss of capitalized net earnings is about \$1,000,000,000." (5) The opportunity is now ripe for the inventive genius to build cheap dwellings that should come up to all the requirements. If only some of the inventive ingenuity applied in the architecture of fighting and flying machines were spent in the construction of modern and cheap dwellings, the results would prove very useful towards ameliorating existing housing evils.

Diagram showing relative growth of entire population and foreign-born population in the years 1890 to 1910 inclusive.

Shaded areas represent foreign-born.

(The figures for foreign-born in 1910 being estimated.)



HISTORY OF THE HOUSING PROBLEM.

Although new aspects of the housing problem have recently developed, the problem itself has been in existence many years. The history of the Poor Laws of England clearly shows that the English government has long been interesting itself in the question of housing those who were unable to provide for themselves. Those conversant with English history have pointed out that in the reign of Henry the Eighth, powers were conferred upon the municipal authorities to rebuild the house property which had fallen into disrepair during the Wars of the Roses. There is no doubt that in the early part of the eighteenth century, in connection with the matter of insurance, it was the function of the local governments in England to rebuild houses and premises destroyed by fire. It was not, however, until about the middle of the nineteenth century that the Housing Problem assumed any definite shape. At this time, the industrial development of England had brought about the flocking of the rural population towards the centers of industry. Sanitary Science had already begun to gain recognition. In 1841, through the efforts of Lord Shaftesbury, the *Society for Improving the Condition of the Laboring Classes* was formed. Soon after, other societies of the same nature were organized, such as the *Metropolitan Association for Improving Dwellings of the Industrious Classes*, *Improved Industrial Dwellings Company*, and many others, so that by 1906 there had been built in England 46,707 improved houses by 413 co-operative societies at a cost of about fifty million dollars (\$50,000,000). Besides the construction of improved dwellings, England has been very active in passing legislation for better housing, and according to Mr. Dewsnup, "28 Housing and Health Acts passed between 1851-1903. The first of these acts was that of Lord Shaftesbury in 1851 for the establishment of lodging houses for the working classes. The last act was the Housing of the Working Classes Act of 1903."

According to some authorities, work on the Housing Problem has been progressing rather slowly in the United States. "Unsanitary Housing," says Mr. Shadwell, "has not attracted much attention yet in the United States, apart from two or three great cities. Public opinion on the subject of sanitary inspection and regulation appears to be in such an early stage that of those municipal committees which issue reports some do not mention it at all. . . . In America they seem to me to be creating future slums without clearing away the existing ones."

(Pages 28 to 48 inclusive reprinted from the annual report of the Associated Charities, Salem, Mass., 1911.)

The writer of the article on housing in the eleventh edition of the *Encyclopaedia Britannica* says, "If American cities have nothing to learn from other countries with regard to bad housing, they have nothing to teach in the way of reform. They are following Europe slowly and are a long distance behind." Such comment by strangers should spur us on to action in this country and indeed, in the past few years, whether because of the comment or other reasons, many American communities have shown great activity in housing reform. In spite of the bad case that the English writers make out against the management of the housing problem in the United States, much may be said in defense of our course. The fact is that the Housing Problem was recognized in this country as early as 1856 when the first tenement house commission was appointed in New York. Later the United States Commissioner of Labor by the direction of Congress carried on an investigation of the slums of large representative American cities. The Ninth Annual Report is a comprehensive exposition of the work and of the status of building and loan associations in this country. The Eighth Special Report of the Commissioner of Labor, 1895, is a most exhaustive treatise on the question of the housing of the working people. In the Bulletin of the Bureau of Labor, No. 54, 1904, the question of housing the laboring classes in the United States by employers is considered in some detail. These publications show that the United States government has been interesting itself in the question of housing for some time. It is to be regretted, however, that very few housing laws have been enacted in this country. We have no national housing laws and according to Ford H. MacGregor, New York, New Jersey, Pennsylvania and Connecticut are the only states in this country which have passed housing ordinances.

But in the last two years, unusual activity in housing reform has been displayed in many communities so that some cities have succeeded in passing housing ordinances setting higher standards than we might ordinarily expect. The Housing Code of Columbus, Ohio, passed by the City Council of that city, March 7, 1911, is a notable example of such an instance.

EXTENT OF PRESENT INVESTIGATION.

Before choosing the districts which were to be included in the Salem investigation several inspection tours of the various districts in-

habited by the foreign-born population were made, and it was finally decided to take in the following districts: the Polish-Jewish district which included the following streets, Peabody, Ward, Derby and Custom House place; the Greek-Italian district comprising Mill, Creek, and High Streets, High Street Court, and Gedney Court; and finally the district known as the Point, inhabited mostly by the French, which includes a considerable area in the south end of Salem, consisting of Harbor, Palmer, Salem, Park, Prince, Congress, Pingree, Perkins, Naumkeag and East Gardner Streets. The reason for the above grouping is that it was found that the Poles and the Jews, the Greeks and the Italians, respectively, inhabited the same districts. This investigation covered 56 buildings, containing 221 tenements, and aggregating 1485 persons, distributed as follows: 25 buildings, 86 tenements and 633 persons in the Polish-Jewish district; 17 buildings, 49 tenements and 336 persons in the Greek-Italian district; and at the Point, 14 buildings, 76 tenements and 516 persons. In addition to the above, 60 buildings at the Point were measured with reference to lot crowding, which is very marked in that district.

We had no special authority either from the Health or Police Department to enter peoples' homes, and much tact was necessary to gain the desired information. A slight knowledge of Polish, French, Italian and Yiddish was of considerable help in gaining admittance, for on many occasions when the people hesitated, their confidence was immediately gained by addressing them in their own tongue. In fact, it is very essential in such an investigation to have a reliable interpreter when soliciting information among people who cannot understand English. On one occasion a volunteer interpreter, a landlord of several tenements, who was unaware that his language was being understood, when asked for the number of lodgers living in those tenements, took the liberty of making generous deductions of the numbers told him by tenants. In one case when he was told that there were 12 boarders in the house, he translated it into 6 boarders. This illustrates one of the drawbacks in using an unreliable interpreter and also emphasizes the fact that much information thus obtained is of doubtful reliability, particularly with reference to the number of occupants. One thing is certain, however, that in no case is the number of the occupants given higher than it really is.

The sizes of the rooms and percentages of window space were obtained from actual measurements. The percentage of lot occupied

by the buildings was procured by measuring the buildings and obtaining the size of the lots of these buildings from the assessors' books. In some instances, where it was found in the assessor's book that a particular lot had several buildings on it, and only one was measured, it was an easy matter to measure the additional buildings and thus obtain the amount of lot crowding for all the buildings of the lot. All other information was obtained by direct inspection of the premises, and by questioning the occupants of the houses.

CONDITIONS WHICH THE INVESTIGATION REVEALS.

Salem is a rapidly growing city, the increase in its population during the last half decade, 6,000, being larger than any previous increase of like period. Furthermore, this exceptionally large increase consists mainly of foreign-born population, especially of Poles and Greeks. The Polish population according to fair estimates (the United States Census results of 1910 not being available as yet) has increased three-fold, the Greek population six-fold. The total population of Salem in 1910 was 43,697.

The chief industries of Salem are the manufacturing of cotton goods, shoes and leather. The cotton mills give steady employment and rather low wages; while the shoe and leather industries, although paying good wages, give employment for only about seven months in the year. There are also several iron foundries in the adjoining towns of Danvers and Beverly, which draw largely on the Polish population of Salem for their help. The United Shoe Machinery Company of Beverly also employs many men living in Salem.

It will be of historic interest to mention here that in 1826 a committee was appointed in Salem, to report on the practicability and expediency of establishing manufactures in Salem. This committee considered that the establishment of manufactures in Salem would attract many foreigners and that slums or rather undesirable foreign quarters would be established in the city as a result of such a step. The report of this committee has obviously exerted very little influence in stopping manufacturers from coming to Salem. The industries have come to stay, the foreign-population has entrenched itself in the city and is growing rapidly.

In 1877 a commission was chosen to investigate and report upon

the drainage and sewerage of the city of Salem. This commission even at that early date realized the effect of bad housing on the people. In discussing an epidemic of diphtheria in 1876 in Salem, the commission says in part, "Ill ventilated apartments, extremes of temperature in rooms which must be used at one and the same time for cooking, washing, dining and living room, reeking odors from foul yards and dirty stairways, decomposing refuse in the cellars, and the crowding of large families in small apartments form a combination of circumstances (in which filth is very prominent) which diminish the power of resistance to any morbid poison." It is a wonder that Salem, having realized the importance of housing so long ago, should have done so little toward bettering conditions, and that even at the present time it should have practically no laws or ordinances which refer to housing. It should be the duty of every community to provide itself with an efficient Sanitary Code and to see to its enforcement. Nor is there any excuse for a community's failing to make housing regulations.

There are practically no housing ordinances in Salem, and it is really remarkable that housing conditions are not worse than they are. The only ordinance with reference to housing is that which limits the number of occupants in any sleeping room to the extent that there shall be 400 cubic feet of air per occupant in case of adults and 200 cubic feet per occupant in case of children under 12. There is another ordinance with reference to fire, namely, that all buildings within the fire limits shall be provided with rear stairs or with fire escapes. Both of these ordinances are of very limited value; the first because it cannot be enforced, as it is almost impossible to find out exactly how many persons are occupying one room, unless inspections are made during the night when the occupants are asleep. The second ordinance is of limited value because it does not seek the prevention of fire, but only safety for the occupants after the fire has started, and even to that end its value is restricted, for in case of fire scant safety is afforded to the occupants of a four-story wooden tenement house, when the only means of escape are rear wooden stairs.

The need of outside iron fire escapes, especially at the Point, is very urgent. The only means of escape in case of fire, afforded by these four-story buildings are, as before stated, rear wooden stairs which are far from being adequate provision. There is no doubt, that if a fire should ever get a good start in that district during the night,

many lives would be lost owing to the lack of proper fire escapes. Several two story dwellings were found which were not even provided with rear stairs.

The dangers from conflagration at the Point are very great. Double four-story wooden tenement houses are common in this district, and the buildings are literally piled one on top of the other as the percentage of the lot crowding in that district (table 5) and the photographs taken will illustrate. What is more, the Fire and Police Departments are well aware of the dangerous condition obtaining here. The fire chief says that in case of any serious fire at the Point



the entire district is doomed, yet nothing has been done to remedy present conditions or to prevent like developments in other sections of the city.

Lot crowding is at present mainly confined to the Point, although there is every reason to believe that this phase of the housing evil will soon spread to other districts unless some ordinance is passed to prevent it. Already in the Greek-Italian district there is one eight family tenement house, occupying 96 per cent. of its lot, built this year. At the Point, 33 per cent. of the buildings measured occupy more than 75 per cent. of their lots, or in other words about 33 per cent. of the lots are over crowded according to the New York regulations. Should we consider the regulations of the Building Code of Colum-

bus, Ohio, which limits the percentage of lot covered by a building to 50 per cent. about 71 per cent. of the lots in Salem are overcrowded. Instances where over 90 per cent. of the lot is occupied are not infrequent, and in a few cases 98 per cent. of the lot was found to be taken up by buildings. The results of such lot crowding



Eight Family Tenement House Built in 1911. 96 per cent. of the lot occupied.
The stairs seen in the picture are the only Fire Escapes required by Law.

will be more clearly illustrated by the photographs, showing the way certain buildings are practically crowded one on top of the other. Lot crowding eventually results in the shutting out of sunlight and in bad ventilation. Then again, the greater the percentage of lot occupied by the building, the less space is left for a yard, and thus the children are forced to play in the streets, where their lives and

limbs and their moral development are endangered. Such conditions as these are easily prevented by legislation, and when a community fails to enact such legislation it fails in its duty.

Room crowding (table 3) is prevalent throughout the foreign-born population, especially in the Polish-Jewish district. This is, no doubt, due to the large number of lodgers whom the Poles usually accommodate. 80 per cent. of the Polish population investigated were found crowded to more than 2 in a room. Of these, 58 per cent. were more than 3 in a room, and 17 per cent. more than 4 in a room. In the Greek-Italian district room crowding was found as



Building in the rear occupies 94 per cent. of its lot.

prevalent as among the Poles, but not to such a great degree; 80 per cent. of these people sleeping in rooms with more than 2 in a room and 37 per cent. of them in rooms with more than 3 persons in a room. At the Point, room crowding is not so common, yet it is sufficiently prevalent to be considered serious. 73 per cent. investigated are crowded to the degree of more than 3 in a room. Room crowding is one of the worst housing evils and its consequences are many and far-reaching.

"Room crowding", says Mr. Veiller, "is bound up with another social problem; namely, the lodger evil. This prevails chiefly among the foreign elements of the population, more especially among the

Italians and Poles. It is fraught with great danger to the social fabric of the country. It means the undermining of family life; often leads to the breaking up of homes and families, to the downfall and subsequent degraded careers of young women, to grave immoralities. in a word to profanation of the home." The



room crowding problem is the more grave because it is more difficult to prevent. As pointed out previously, legislation on this score is almost impossible to enforce.

With regard to cubic air space per occupant, the following conditions were found (table 4). At the Point, 61 per cent. of the people are sleeping in rooms which provide on the average from 200 to 400 cubic feet of air per occupant. In the Polish-Jewish district 70 per cent. of the people are sleeping in rooms containing from 200

to 400 cubic feet of air per occupant while 7 per cent. are sleeping in rooms of less than 200 cubic feet per occupant. In the Greek-Italian district, 71 per cent. of the people are sleeping under conditions of 200 to 400 cubic feet of air space per occupant, and 2 per cent. in rooms less than 200 cubic feet per occupant. In considering the amount of air space per occupant it must always be borne in mind



that the standard of 400 cubic feet per occupant adopted in many cities is an arbitrary one and that the mere fact of people's sleeping in rooms having less than 400 cubic feet of air space does not necessarily signify bad conditions. In fact, rooms which are well ventilated, having the windows open to the fresh air, are much more healthy even if the amount of cubic feet per occupant is less than

200 cubic feet, than are rooms of 500 cubic feet per occupant with windows shut tight and no ventilation. The amount of cubic feet per occupant is important, however, as it indirectly indicates the extent of crowding. As a result of these conditions one of the great housing problems yet to be solved, especially in large cities where space is very valuable, is how to provide artificially well ventilated rooms without having to depend upon cubic air space and natural ventilation. Even in some of the so-called model dwellings the ventilation is rather unsatisfactory. After all, it is not the quantity of air which plays the important part in ventilation. Surely 200 cubic feet of moving, fresh, cool air of the proper humidity is infinitely better than 1000 cubic feet of stagnant, hot, foul air.

With reference to light and ventilation there is no doubt that conditions might be greatly improved. At the Point where the houses are built so closely together, lower dark tenements are very frequent, although the tenements on the upper floors are, as a rule, well lighted. In the question of light and ventilation the amount of window space in a room is very important, and the following conditions were found (table 6). 5 per cent. of the rooms at the Point have window space amounting to less than 8 per cent. of the total floor space. The ordinances with respect to window space vary in many places, some requiring 8 per cent., others 10 per cent. and still others 12 per cent. of the total floor space. In the Polish-Jewish district 19 per cent. of the rooms have window space amounting to less than 8 per cent. of the total floor space, while in the Greek-Italian, 4 per cent. of the rooms have window space less than 8 per cent. of the floor space. Another point with reference to ventilation, is the importance of having the windows open at the top, for better results may thus be obtained. Many people will not open the windows at the bottom for fear of a draft. In many of the old houses the windows are not made to open at the top. The percentage of rooms having windows opening only at the bottom is greatest in the Polish-Jewish district. Here they amount to 48 per cent. of the total rooms investigated. In the Greek-Italian district, 38 per cent. of the rooms have windows not opening at the top.

In general the plumbing of the houses was found to be in good condition, and there is no doubt that the excellent plumbing ordinances which Salem has, combined with inspection, is largely responsible for this. Privies were found in the Polish-Jewish and in the Greek-Italian districts. This is only mentioned in passing, for their re-

moval is in progress. There is one bad feature with reference to the water closets that should be mentioned. Many of them are situated either outside or in the cellar, and all investigated are used by two or more families (table 7). In the Polish-Jewish district at least 31 per cent. of the water closets are located in the cellars and are



each used by two, three and four families. Practically all of these water closets were found in very unsanitary condition, and quite naturally too. Each family claimed that the other family was responsible for the condition and since the owner did not seek to remedy the evil no one else did. In the case of typhoid fever, such conditions as these play a very important part in the dissemination of the disease.

As far as the general cleanliness is concerned, the following conditions were found (table 8). At the Point, 50 per cent. of the cellars, 21 per cent. of the tenements and practically all the yards (with the exception of the yards of the Naumkeag Steam Cotton Company), were dirty, while 4 per cent. of the tenements were filthy. In the



Greek-Italian district 34 per cent. of the cellars, 60 per cent. of the tenements, and 88 per cent. of the yards were dirty, while 26 per cent. of the cellars and 12 per cent. of the yards were filthy. In the Polish-Jewish district, 48 per cent. of the cellars, 43 per cent. of the tenements, and 68 per cent. of the yards were dirty, while 30 per cent. of the cellars, and 2 per cent. of the tenements, and 20 per cent.

of the yards were filthy. There are many factors contributing to dirty and filthy conditions. Perhaps the time of the year (the latter part of winter and the early part of spring) in which the investigation was made, is somewhat responsible for the conditions of the cellars and yards. At this particular time people are more likely to neglect their yards and cellars. At any rate we must bear this fact in mind in drawing any conclusions. Some tenements are dirty because of the habits of the people living in them, while other tenements are dirty because of their crowded condition. Legislation and ordinances can accomplish little with regard to cleanliness. It would require entirely too many inspectors to enforce such ordinances. The only way to make people clean is to educate them, so that they themselves will realize the importance of cleanliness.

Of all the tenements that were investigated, only three were found that have bathing accommodations. This lack of bathing facilities is the more serious as there are no free public baths in Salem. The fact to be emphasized, however, is the lack of free public baths, for bath accommodations in tenements would mean higher rents than most people can afford to pay.

Some of the houses of the Naumkeag Steam Cotton Company were purposely investigated, that comparisons might be made. This company owns about 125 tenements of 3 and 6 rooms each, and charges a rent of 25 cents a room per week, which is about one half of the rent of the other houses. The only requirement of the company is that at least one member of the family shall be in their employ. The conditions of these houses compared very favorably with the other houses; the yards are well drained and clean, the houses are built at a sufficient distance apart to admit plenty of sunlight, and the tenements and buildings are kept in good repair. These houses are $2\frac{1}{2}$ stories high, accommodating four families each and provided with outside iron fire escapes. Crowding, however, is present in these tenements also, and in one of the tenements occupied by a Polish family were found 15 people sleeping in 5 rooms. This again illustrates the difficulty in preventing room crowding.

Generalization from few and exceptional cases is dangerous. We have, therefore, in drawing our conclusions, endeavored to consider only typical cases which are truly representative of general conditions. It may be added, however, that conditions are, perhaps, worse than we have attempted to show. Certainly they are not better.

CONCLUSIONS TO BE DRAWN AS A RESULT OF THE INVESTIGATION.

From the foregoing pages it is evident that Salem is rapidly becoming a cosmopolitan city. With the development of its industries and the rapid increase in the foreign born population, slums and other housing evils are bound to spread and grow, unless some definite steps are taken to prevent them. In comparing Salem with large cities, such as New York or Boston, one cannot say that the housing conditions here are as yet very grave, nevertheless, when we consider Salem by itself we must admit that the local situation is serious, and unless the matter receives immediate attention our housing evils will equal those of larger cities.

The room crowding prevailing in Salem is in part due to the fact that there is an insufficient supply of housing accommodations. The old houses in the Polish-Jewish and Greek-Italian districts are inadequate to supply the demand and a sufficient number of new houses have not yet been erected. In speaking to one of the Italian landlords, who owned several houses on Creek Street, we were told that the demand was so great that the people themselves offer higher rents in order to obtain tenements. This is a strong indication that the Jerry-Builder will soon get busy in this district and revel in the lack of proper building regulations. Never before did Salem find itself in a greater need of proper building ordinances. There is still time, however, if a proper building code is enacted at once, to prevent more serious conditions in the future.

REMEDIAL AND PREVENTIVE MEASURES TO BE UNDERTAKEN.

Many remedies for the prevention of housing evils have been offered. Legislation governing the details of construction of new buildings to be erected, the building of model dwellings by business corporations or philanthropic associations, city planning and municipal housing are but a few of the remedial measures which have been suggested. There is no cure-all remedy for housing evils. The remedies for bad housing must proceed from many directions, and progress toward housing reform is necessarily slow. We cannot hope to establish housing reform which will secure ideal conditions. If, however, we work on the principle that half a loaf is better than none, we can succeed in bringing about reform which will greatly alleviate present conditions.

Before attempting to provide itself with a Building Code and new Health Ordinances, the City of Salem can greatly improve the pres-

ent situation by enforcing the health ordinances already in existence which pertain to cleanliness of premises, room crowding and removal of privies. We shall not attempt to say how to enforce these ordinances, but will venture to suggest that more frequent inspection be made possible by a larger staff.

The City of Salem is certainly in urgent need of a Building Code which shall govern the detail of construction of new buildings. Such a code should make provision first, for light and ventilation, that is, percentage of lot occupied, height of tenement houses, yards, space between buildings, size of rooms, window space and other details which it is beyond this report to consider. Second, for sanitation, that is, number and location of water closets in tenement houses, proper water supply and plumbing, and maintenance of cleanly conditions. Third, for fire protection, that is, such provisions as to the size of the tenement houses, material used, arrangement of stairs and other details which shall reduce the fire risk to a minimum. The plans of buildings to be erected should be approved by a competent architect, conversant with the Building Code and in the employ of the city. The drafting of a Building Code is a very difficult matter, and its success or failure will depend largely on its clearness and definiteness. There is also danger of overdoing, that is, making unreasonable demands which will prevent people from building and thus create a house famine. Too much law is often as bad as no law and should be avoided.

Although legislation will be of great value to prevent future evils, it is not well to depend on legislation alone. Other remedial measures should be instituted. The erection of model dwellings by well organized business concerns, on absolute business principles, and at rentals within the reach of the poorer classes is a remedial measure which will guarantee the future and also improve present conditions. Any movement toward the erection of model dwellings should be on a large scale. The erection of one or two or even of a dozen such dwellings will be of but little value in bettering housing conditions. A sufficient number of these model dwellings, properly managed and well advertised, would render unnecessary the undesirable tenements. If conducted on business principles, there is no reason why such an enterprise should not pay reasonable dividends. We think that the Jerry-Builder would soon either have to improve his methods or go out of business. Many corporations have already been formed in this country for the purpose of erecting model dwellings, and wherever

these corporations were established on a purely business basis the results have proved satisfactory, both as a business venture and as a housing reform movement. In an article on housing which appeared in the *Review of Reviews*, February, 1911, the author quotes from the last annual report of the City and Suburban Homes Company of New York as follows: "The company's buildings shelter each year a larger proportion of foreign-born population, and it may be that they will become more and more a halting place, with badly congested tenement environment as a starting point, and wholesome suburban life as the goal. The company's tenants, as a whole, are more self-respecting than the average tenement dweller, but they are not on the average more prosperous. The statement frequently made that model tenements become the homes of people who can afford higher rentals, is not true so far as the experience of this company with its own buildings is concerned."

After all is said and done about legislation and the erection of model dwellings, there still remains another and perhaps a more fundamental remedy; namely, education of the people. The greater part of the existing housing evils can be eventually traced to a lack of education of the people. Our present methods of education are in general rather old fashioned, and the education of our foreign-born population, especially the older element, is entirely neglected. It is a popular fallacy to consider the teaching of reading and writing of English to the immigrant the principal thing. The truth is, we should educate them in our way of thinking, which can often be done most effectively by appealing to them in their native tongue. It is far more important to make the foreign population think our way than talk our way. We must appeal to them by means of circulars and bulletins printed in their own tongues, pointing out the advantages of good homes and the dangers of bad. They should be made to realize for themselves that they must avoid crowding, not because it is against the law, but rather because it is for their own welfare. Trained inspectors speaking different languages should be sent around to teach them the first principles of sanitation. We must make them feel that they are an important part of our community and that their co-operation is needed for the betterment of conditions.

A well-organized campaign of education should be carried on. Illustrated free lectures on the subjects of housing and sanitation should be given, not only in English, but also in Polish, Italian, Jewish and Greek, and these should be supplemented by a free distribu-

tion of pamphlets in the native tongues on the same topics. These measures, combined with intelligent and trained inspection, must yield telling results in the line of housing reform.

As before stated, there are no cure-all remedies for bad housing. The problem of housing of the poorer classes is but a sub-division of the great social, economic, and ethical problem of the human race. These remedies are offered, not because they will entirely remove the housing evils, but because when properly carried through, they will bring about far better conditions than those now existing.

Table I.

**OVERCROWDING AND DEATH RATES.
ADMINISTRATIVE COUNTY OF LONDON.**

Death Rates per 1,000 living.

Proportion of total population living more than two in a room				From all causes		from Phthisis	
				1899	1901	1899	1901
District with under	10%			15.22	14.5	1.18	1.26
"	"	"	10-15%	17.13	16.2	1.52	1.52
"	"	"	15-20%	19.13	18.1	1.68	1.64
"	"	"	20-25%	20.49	19.0	2.00	2.06
"	"	"	25-30%	20.48	20.9	2.13	2.27
"	"	"	30 and more	24.07	21.0	2.16	2.13

Table II.

**ANNUAL DEATH RATE PER 1,000 LIVING DURING
FIVE YEARS IN BACK-TO-BACK HOUSES,
MANCHESTER.**

Groups	Total popu- lation	Percentage of Back-to-Back houses	All causes	Common infectious diseases	Con- sumption	Other lung diseases	Diarrhoea
I	8,713	0	27.5	4.5	2.8	6.6	1.4
II	11,749	23	29.2	4.8	3.3	7.8	1.6
III	11,405	56	30.5	6.2	3.6	7.9	2.1
IV	892	100	38.4	8.7	5.2	9.2	3.4

This table was taken from Dewsnap, R. E., "The Housing Problem in England," pp. 27 and 29.

